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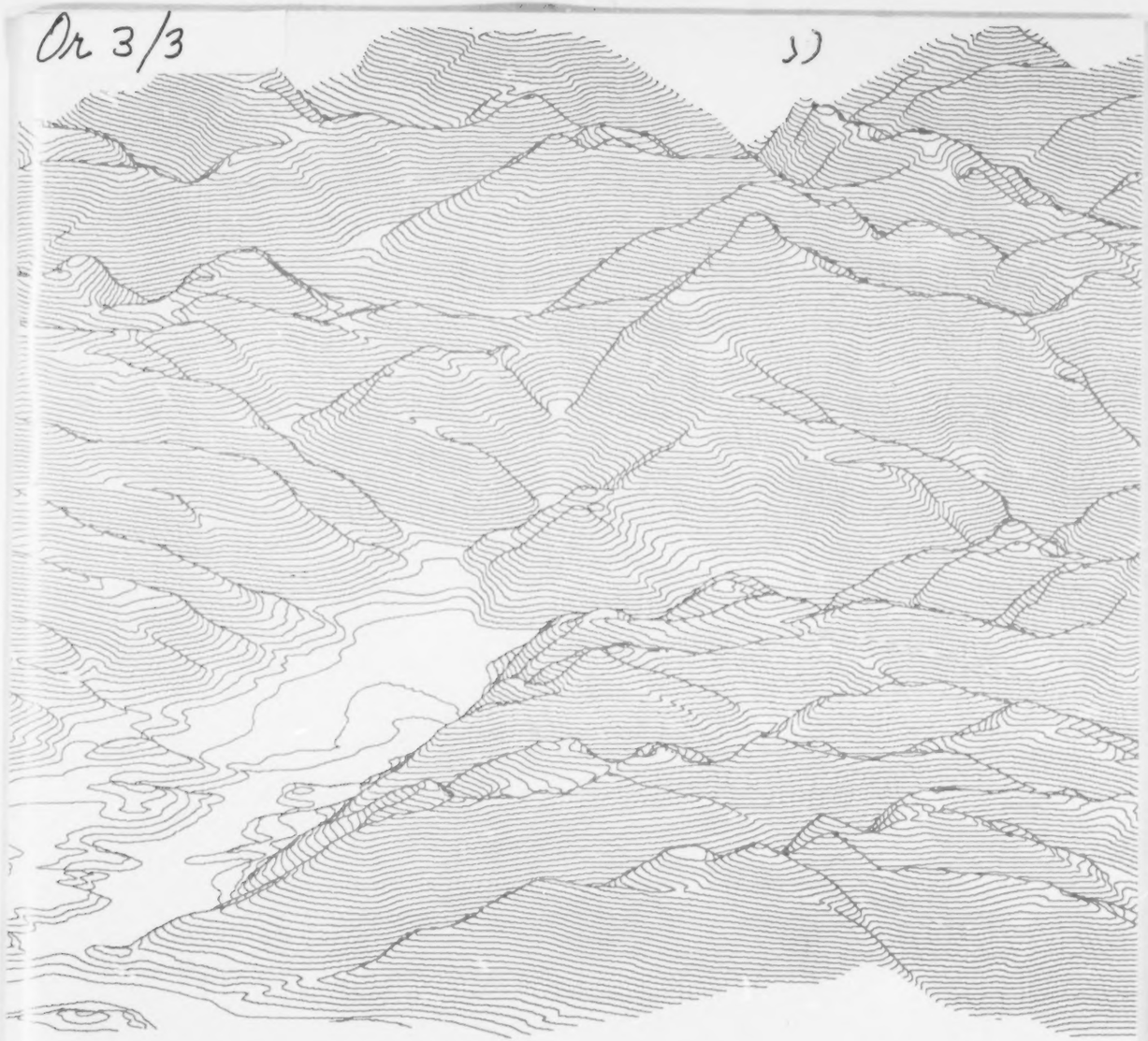

Organizational Activities

U.S. Army
Engineer Topographic Laboratories
Fort Belvoir, Virginia

Organizational Activities

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For further information contact:

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U.S. Army Engineer Topographic Laboratories
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Introduction

The U.S. Army Engineer Topographic Laboratories (ETL) conducts research and development in the topographic sciences and prepares terrain analyses for the military community. The equipment, techniques and terrain information produced by ETL's scientists, engineers and analysts will help U.S. forces fight and win the AirLand battle.

Terrain plays an important role in combat. The commander who takes advantage of it increases his ability to defeat the enemy—to fight outnumbered and win! The Army's major operational manual, FM 100-5, recognizes the importance of terrain to modern combat: "Weather and terrain have more impact on battle than any other physical factor, including weapons, equipment, or supplies." Engineer doctrine highlights topography as one of the combat engineer's five main battlefield missions. In addition, topography actually supports the other four. The successful accomplishment of these missions — mobility, countermobility, survivability and general engineering — is affected by the engineer's ability to take advantage of a knowledge of the terrain. Topographic support provides a basic and critical force multiplier.

A field operating activity of the Corps of Engineers, ETL directs its primary efforts toward improving the combat capabilities of U.S. forces. Scientists are working on techniques and equipment which will give commanders in the field the fast, accurate topographic support they need. Researchers are also exploring ways to improve the Defense Mapping Agency's base plant topographic capabilities.

The Laboratories' research and development efforts concentrate on the following areas of topographic support: mapping and cartography; point positioning and targeting; surveying and navigation; terrain analysis; and weapon system support. ETL is an active participant in the Corps' AirLand Battlefield Environment thrust — a program which will give the Army new ways to monitor and exploit the battlefield environment. ETL also produces operational terrain analyses and supports the Corps' civil works program.

This book describes ETL's work in these and other areas. Although it focuses on current research, it also highlights the Laboratories' recent accomplishments and provides a guide to the future. The techniques and technologies being developed at ETL today will help defend the nation tomorrow.

With an annual budget of more than $50 million and a staff of approximately 300, ETL directly supports a variety of Army and Department of Defense agencies. Scientists are currently working on projects for the Army Materiel Command, Army Space Program Office, Corps of Engineers, Defense Mapping Agency and Defense Advanced Research Projects Agency.

To accomplish its mission, ETL is divided into five major components. These working groups include three developmental laboratories, a center for basic research, and a terrain data production unit.

The **Geographic Sciences Laboratory** develops new techniques and equipment for extracting, storing, analyzing and displaying military geographic information. This lab also studies the effects of the environment on military materiel.

The **Topographic Developments Laboratory** focuses on surveying and mapping. Much of its work involves designing new computer programs and equipment for map production. Its scientists also develop improved survey techniques for the field Army and civil works community.

The **Computer Sciences Laboratory** investigates advanced computer techniques for processing and analyzing digital imagery. Its scientists provide consulting and support services to other ETL organizations in the areas of mathematical modeling, simulation and computer applications.

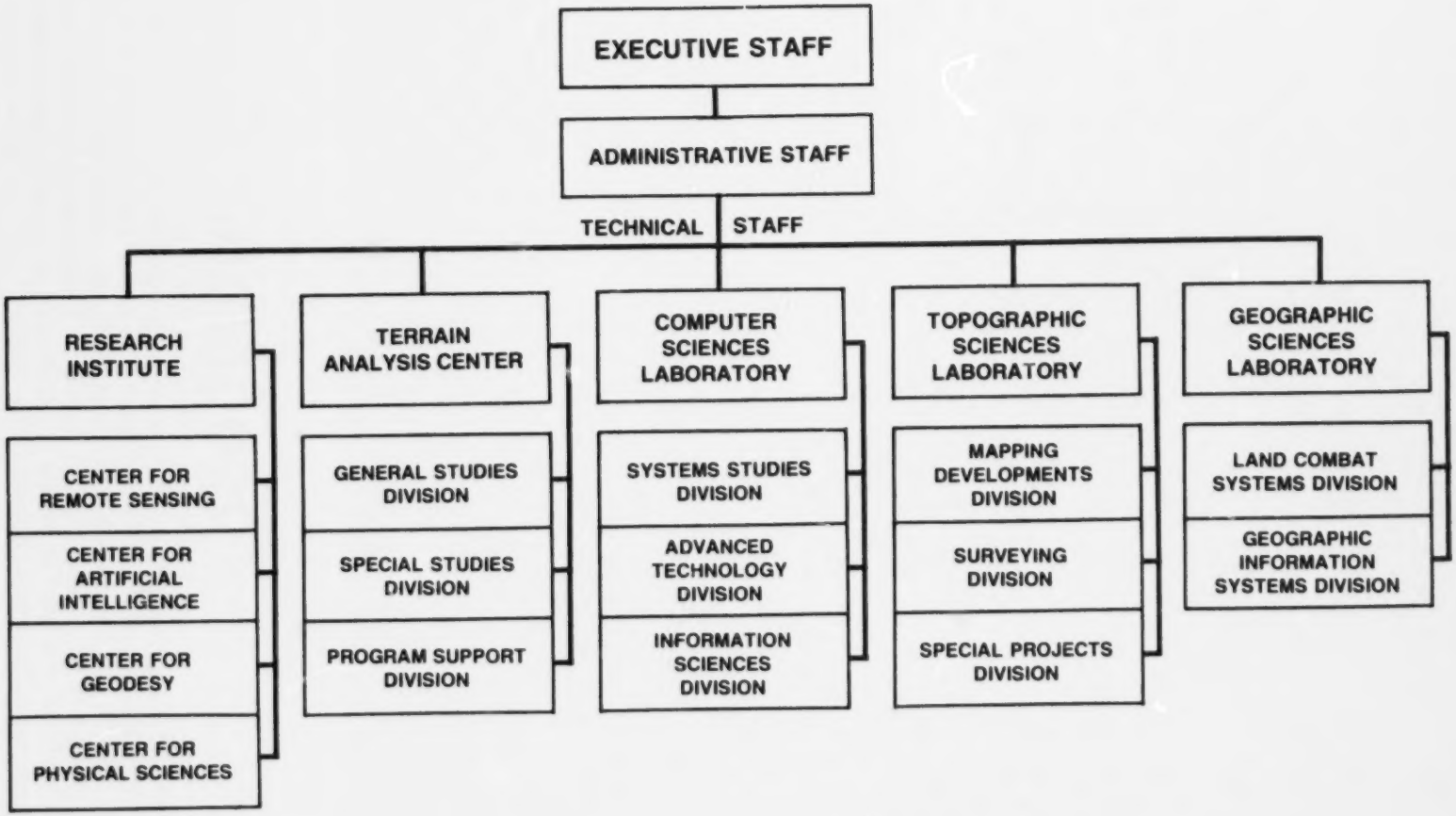
The **Research Institute** performs basic and applied theoretical research in remote sensing, artificial intelligence, geodesy and the physical sciences. Much of its work focuses on manual, interactive and automated techniques for extracting terrain information from different types of imagery. Its research fuels the developmental efforts of the other labs.

The **Terrain Analysis Center** prepares terrain studies to support military planning and operations. The Center also maintains a data management capability for worldwide geographic information and serves as a testing ground for new terrain analysis methods and techniques.

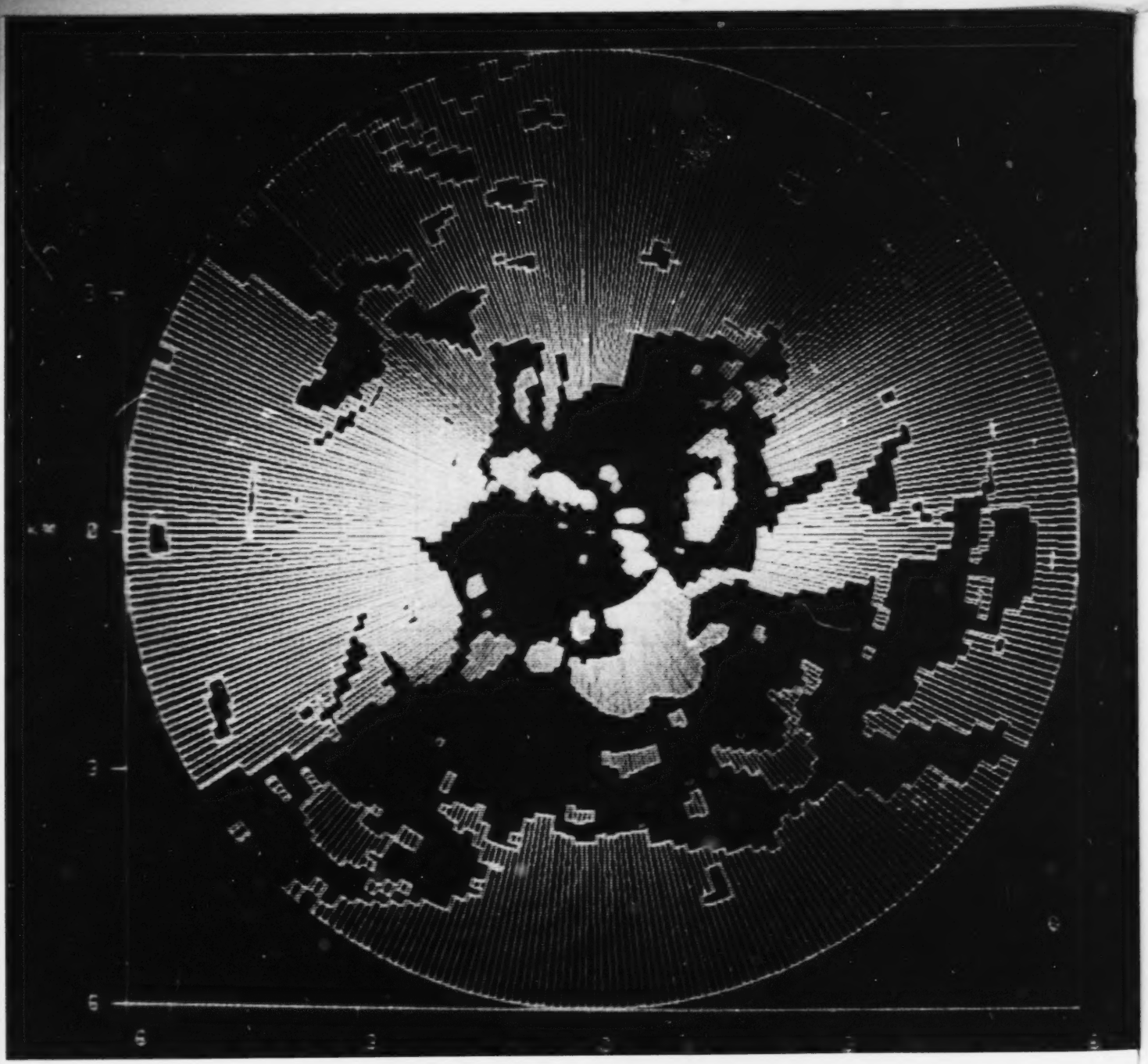
As a member of the Federal Laboratory Consortium, ETL actively encourages multiple applications of its research developments. George Simcox, Office of Research and Technology Applications, is the point of contact for technology transfer (202/355-2629). The agency also publishes a quarterly information exchange bulletin, *Tech-Tran*, which is available free upon request.

ETL participates in the Corps of Engineers' Installation Support/One-Stop R&D Services program — a program which provides technical advice and assistance to Corps districts, divisions and facilities engineers at Army installations. ETL scientists can help these groups handle problems in such areas as mapping, point positioning and military geographic information.

Located 15 miles south of Washington, D.C., ETL welcomes visits from individuals and groups. Additional information on the agency's research and development activities may be obtained by contacting the U.S. Army Engineer Topographic Laboratories, ETL-LO, Fort Belvoir, Va., 22060-5546 (202/355-2634).



Organization Chart



Topographic Support

Combat commanders need to know as much as possible about the battlefield if they hope to control the action upon it. The Army's increased reliance on speed and mobility makes timely and accurate terrain information more important than ever.

At present, terrain analysts manually assemble and analyze such information. Today's terrain teams cannot generate terrain products with the speed needed to support modern combat. Producing a single tactical terrain graphic can take hours of labor. Printing copies of that graphic means additional delays.

Commanders must have terrain information to plan and carry out combat maneuvers. Many of the Army's new automated weapon and intelligence systems also need terrain data. Topographic units in the field today cannot store, process or produce the volume of data which future users will demand.

Researchers in ETL's Geographic Sciences Laboratory are working to improve and expand the Army's topographic support capabilities. Procedural guides prepared by lab scientists are already helping terrain analysts on the job. Current ETL research efforts will allow terrain teams to produce — and reproduce — topographic products and data with increased speed and accuracy.

Scientists have developed analytical software programs which generate tactical terrain graphics in a fraction of the time now required. Researchers are investigating new ways to extract terrain information from source materials. They're also perfecting techniques for building and revising geographic data bases.

Efforts are under way to field these capabilities. The planned Digital Topographic Support System will automate many terrain team functions. This comprehensive terrain data system will provide commanders the terrain information they need to map out their battle plans. It will keep a variety of automated battlefield systems supplied with digital topographic data.

Topographic support also involves reproducing terrain information. A new field printer being developed by ETL will make it easy for soldiers to copy terrain graphics, special purpose maps and related materials. This equipment will reproduce hardcopy originals. In the future, it will be able to print paper products from digital data files.

Most of the projects described in this chapter will result in new topographic techniques and equipment for the field Army. ETL researchers are also exploring other applications for the technologies involved in these efforts. Scientists are using digital terrain data bases, image processing techniques and computer technology to investigate the navigation problems associated with robotic vehicles. They've also studied and demonstrated techniques for building geographic data bases to support resource management and other civil works functions.

Procedural Guides

In 1984, ETL scientists completed a series of terrain analysis and synthesis procedural guides. These guides offer on-the-job assistance to the soldiers who produce military geographic information in the field. They also provide an important tool for training terrain analysts.

The guides show soldiers how to examine source materials, and extract and synthesize terrain information. Analysis guides give step-by-step manual procedures for assembling basic terrain data. Synthesis guides present detailed instructions for combining this information into complex products which show how the terrain affects specific military operations. Both sets of guides focus on the "how to" aspects of terrain analysis. They do not develop or explain underlying theory.

Soldiers use the analysis guides to extract data from maps, photographs and other sources and prepare simple, single-color overlays registered to a standard 1:50,000 scale topographic map. Each overlay depicts a different terrain factor (vegetation, drainage, soils, slope, etc.) and includes supporting data tables. Taken together, they form a thematic graphic data base for the area under examination.

The synthesis guides help analysts use this data base to predict terrain effects and produce map-type terrain studies which deal with such tactical concerns as cross-country movement, cover and concealment, lines of communication and airfield sites. When sufficient quantitative data exists, soldiers can use programmable calculators and simplified analytical models to combine information. The guides also outline manual procedures that rely on precalculated tables and graphs; if the data base is incomplete, analysts can insert subjective estimates and judgments.

The completed analysis series includes guides on vegetation, geology, roads and related structures, drainage and water resources, climate, soils, surface configuration, railroads and built-up areas. Synthesis guides on cross-country movement, obstacle siting, lines of communication, river crossings and minefield siting have already been published. A guide on helicopter landing and drop zones has also been prepared.

These procedural guides have been used to produce terrain data in the field and to train soldiers assigned to terrain detachments. Although they deal exclusively with manual operations, they contain the basic algorithms needed to automate parts of the terrain analysis function. ETL scientists have already incorporated synthesis techniques documented in the

guides into interactive software routines. These programs will help speed the terrain analysis process.

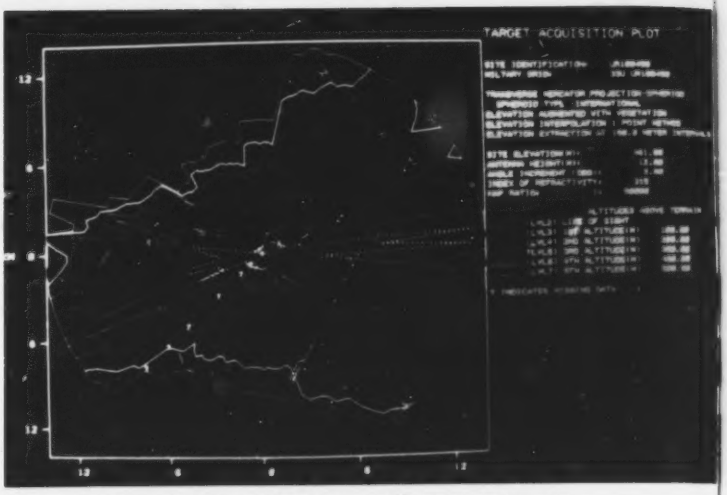
Terrain Analysis Software

Automation provides the key to recent ETL efforts to upgrade the Army's field topographic capabilities. Scientists have successfully developed and demonstrated automated terrain analysis techniques in the laboratory. They've used an interactive computer graphics system to design and test software programs which handle many of the analytical tasks involved in preparing terrain products to support tactical planning and combat operations.

This experimental Digital Terrain Analysis Station (DTAS) produces complex terrain graphics by combining the performance specifications of the Army's vehicles, weapons and communications equipment with terrain elevation and feature data. A digital topographic data base covering several adjacent 1:50,000 scale map sheets provides the raw material for the system's software programs. This data base contains elevation values and information on slope, soil, vegetation, water bodies, urban areas, roads, railroads and waterways.

DTAS analytical capabilities address the tactically important questions of intervisibility and mobility. Intervisibility models determine areas that are visible (either optically or electronically) from a given site. They compensate for the curvature of the earth and atmospheric refraction. These models rely primarily on digital terrain elevation data, but users can include vegetation heights in the analyses. Intervisibility models developed in the laboratory include terrain profiles, target acquisition plots, masked area models, perspective views and path loss/line-of-sight analyses.

Scientists have used an interactive workstation to develop and evaluate automated terrain analysis software.



This target acquisition plot maps out the coverage provided by a radar unit located at the center.

Mobility models use digital feature analysis data to evaluate the effects of the terrain on friendly and enemy operations. Mobility products address such factors as cross-country movement, concealment and lines of communication. Other models identify river crossing sites, air avenues of approach and helicopter landing and drop zones.

These graphics can help commanders move and maneuver their men and equipment with greater effectiveness. The accompanying chart lists the terrain analysis tactical decision aids completed to date. Selected models are described in more detail below.

Target acquisition: This model determines the points at which incoming targets first become visible to observers or electronic sensors. Target acquisition graphics can depict the sighting contour for a single altitude or for a number of altitudes for any observation sector from 0 to 360 degrees. Multiple altitude plots use color-coded concentric polygons to map out the acquisition contours for each altitude. These graphics can help commanders position radar units for optimal coverage.

Perspective view: This model presents a view of the terrain in full perspective. Perspective graphics consist of a grid of equally spaced lines which follow the changing elevations of the earth. The resulting "fishnet" appearance of the terrain gives the viewer important cues for depth perception. By changing input parameters, commanders can see how the land would look from any location.

Cross-country movement: This group of graphics displays off-road speed capabilities for user-selected vehicles. Cross-country movement (CCM) analyses take into account the land's slope, soil and vegetation as well as the performance characteristics (stability,

power, etc.) of the vehicle involved. Weather effects can also be included in the modeling. Once the CCM graphic has been produced, analysts can add roads, rivers and urban areas to the picture.

Concealment: This model determines the amount of concealment provided by the vegetation in an area. Graphics depict concealment for troops and equipment in terms of the extent to which they risk detection by aerial reconnaissance. Areas mapped out as having a 0 to 25 percent probability of detection offer the best concealment potential. Commanders, however, would avoid those sites that show a 75 percent or greater chance of detection.

Lines of communication: This product can help commanders analyze routes and evaluate the enemy's possible course of action. The model combines vehicle information with data on roads, bridges, tunnels and other terrain features. The resulting graphics map out alternate routes and show the time and distance involved in reaching selected destinations.

These software capabilities will reach the field via the Digital Topographic Support System.

Terrain Analysis Tactical Decision Aids

INTERVISIBILITY	MOBILITY
Terrain Profile Plot	Cross-Country Movement
Target Acquisition	Lines of Communication
Multi-Site Target Acquisition	River Crossing
Composite Target Acquisition	Drop Zones
Masked Area Plot	Helicopter Landing Zones
Perspective Plot	Air Avenues of Approach
Path Loss/Line-of-Sight	Concealment
Flight Line Masking	Barrier and Denial
Minimum Detection Altitude	Infiltration Zones
Oblique Projection	Local Relief
	Slope
	Key Terrain

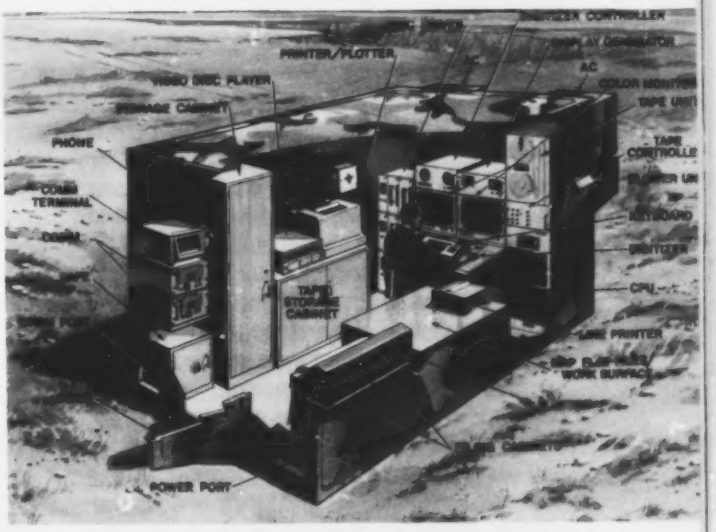
Digital Topographic Support System

The Digital Topographic Support System (DTSS) will put the speed and flexibility of automation to work for the terrain analyst.

Scheduled for fielding at the end of the decade, this automated terrain data system will give Army terrain teams the ability to manipulate digital terrain information and generate tactical terrain graphics. DTSS will also supply the digital topographic data needed to support such automated battlefield systems as the All-Source Analysis System (ASAS) and FIREFINDER countermortar counterartillery radar.

DTSS will replace the manual methods currently used in the field to store, process and analyze terrain data. The system will take advantage of modern electronic data processing techniques and computer graphics technology. DTSS software programs will help analysts produce terrain products that support tactical planning and decisionmaking. Planned hardware components include digital plotters, interactive graphic workstations, and on-line and off-line storage devices.

ETL scientists have already developed most of the software needed to make DTSS a comprehensive terrain analysis system (see preceding entry). Efforts are under way to build prototype hardware modules for the project.



The Digital Topographic Support System will put automated terrain analysis capabilities in the field (top). Soldiers will use computers to analyze terrain data and generate terrain graphics (bottom).

The Army plans to field DTSS in three overlapping phases. As the first phase of this effort, ETL researchers are assembling an initial operational system designed to provide topographic products for ASAS support.

ASAS is an automated intelligence system which is

being developed by the Joint Tactical Fusion Program Management Office (JTFPMO). It will improve the Army's intelligence analysis and electronic warfare support capabilities.

The first DTSS units to reach the field will support such ASAS functions as intelligence preparation of the battlefield and sensor management. DTSS mobility graphics will help commanders identify aircraft flight paths, mobility corridors, helicopter landing and drop zones and river crossing sites. Intervisibility products will answer queries concerning communications, electronic warfare and sensor positioning. Analysts will have access to softcopy map background displays.

ETL scientists are working closely with JTFPMO officials to ensure DTSS/ASAS compatibility. The two systems will have maximum hardware and software commonality, similar equipment support and maintenance requirements, and identical reconnaissance signatures.

DTSS program plans call for fielding baseline systems at division and corps level in fiscal years 1989 and 1990. The second phase of the program will expand the system so that it can support other Army users of digital topographic data. This upgraded DTSS will serve such "customers" as FIREFINDER, the Corps Support Weapon System, helicopter cockpit displays, Very Intelligent Surveillance and Target Acquisition (VISTA) systems, mission simulators and other automated tactical and training systems.

During this phase, DTSS units will be fielded at echelon-above-corps. The system will give Army topographic battalions a significantly expanded terrain data manipulation capability. Soldiers manning the DTSS will be able to update and augment digital data bases. The techniques and equipment needed to extract terrain information and build terrain data bases are being developed as part of the Terrain Analyst Work Station project described later in this chapter.

DTSS program plans also include a long-range commitment to state-of-the-art topographic support. Original DTSS hardware and software will be replaced as more advanced components emerge from the laboratory. Developments in such areas as automated data extraction, artificial intelligence, computer image generation and hardware design may eventually expand the system's capabilities and increase its speed and efficiency.

Data Base Evaluation

Digital topographic support can only become a reality if the appropriate data bases exist to support it. The Defense Mapping Agency (DMA) will supply these data bases.

Terrain analysis, however, represents only one use of digital topographic data. Many of the Army's existing and emerging tactical systems, computerized combat models, simulators, training devices and operational displays also need this information.

As part of the DTSS development, ETL scientists prepared a comprehensive study of the Army's present and future requirements for digital topographic data and identified data base specifications which meet these needs. To facilitate this effort, DMA produced two prototype terrain data bases. The Army Materiel Command (AMC) tasked ETL to coordinate the Army's evaluation of these data sets.

During the first part of this evaluation, researchers studied the content, accuracy, resolution and format of the data bases and tested their adequacy for terrain analysis support. Scientists used the software programs described earlier in this chapter (see "Terrain Analysis Software" entry) to conduct this aspect of the study.

ETL's data base evaluation included ground truth studies at Fort Lewis, Wash. Researchers compared computer-generated terrain products with actual ground measurements.

Working with the Laboratories' in-house interactive computer graphics system, researchers produced tactical terrain products from the prototype data sets. They compared these computer-generated graphics with manually prepared products covering the same analytical topics. Both visual and statistical evaluation methods were used. Scientists also conducted ground truth studies to verify the accuracy of the elevation values and feature elements contained in the data bases and validate the synthesized terrain analysis products.

During the second phase of the evaluation, scientists examined the data bases in terms of the requirements for terrain data which will be generated by existing and planned tactical and training systems. As part of this effort, they contacted over 75 Army activities, interviewing both system developers and users.

ETL researchers completed the data base evaluation in 1984 and delivered their findings to AMC. The Office of the Assistant Chief of Staff for Intelligence forwarded the resulting report to DMA as the Army's official statement of its digital topographic data needs.

The Terrain Analyst Work Station includes a light table mensuration system for extracting feature data.

Terrain Analyst Work Station

DMA will provide the Army digital terrain data bases and digital terrain products to support the terrain analysis community and other users. These general data bases and products, however, will not meet all of the Army's requirements, nor will they cover every geographic area that may eventually be of strategic or tactical interest. Even if global coverage were possible, DMA data bases would still need updating to reflect changes in the terrain caused by man and nature.

Today's terrain analysts, working with maps, charts and other sources, must take such changes into account. Even after automation, troops in the field will still need to update and revise terrain data to reflect current conditions. The soldiers who man the topographic units of the future must also be equipped to create new terrain data bases and generate special terrain analysis products.

ETL is developing a prototype Terrain Analyst Work Station (TAWS) in response to these needs. This terrain analysis demonstrator will allow analysts to produce, update, revise and manipulate digital terrain data bases.

In designing TAWS, ETL scientists have taken advantage of recent advances in microcomputer technology, analytical photogrammetry, computer-assisted photo interpretation and geobased information processing. They have procured a state-of-the-art microcomputer and related off-the-shelf peripherals, specialized terrain data extraction and analysis equipment, and geographic information system software. Researchers are working to integrate these hardware and software components into a cohesive terrain data management system.

The 32-bit microcomputer which will provide computational support for TAWS has been installed at the Laboratories. Its peripherals include two 132-megabyte hard disks, a magnetic tape drive, color and black-and-white graphics terminals, a graphic plotter and a line printer. The TAWS computer has been linked to a MICROFIX unit — an Army computer system that's already being used in the field to store and retrieve terrain data. MICROFIX will serve as an input and output device for TAWS.

The TAWS hardware configuration also includes a light table mensuration system and an analytical stereoplotter with stereo superpositioning capabilities. Analysts will use this equipment to make photogrammetric measurements and extract elevation and feature data from aerial photographs. A graphics digitizing table provides additional input capability for non-photogrammetric data.

TAWS 's geographic information system consists of Analytical Mapping System (AMS) and Map Overlay and Statistics System (MOSS) software. Researchers have adapted these programs for TAWS and expanded them to meet TAWS needs. Intervisibility software routines described earlier in this chapter have been installed on TAWS and will be used to generate terrain products from digital elevation data.

After testing TAWS in the laboratory, researchers plan to take the equipment into the field for a series of demonstrations. Soldiers from various units will be trained to operate the system. They'll use it to demonstrate and test TAWS capabilities.

Feedback from the field will help scientists define and develop the data extraction, analysis, update and revision capabilities needed for combat support. These capabilities will eventually be incorporated into DTSS.

Scientists plan to use image processing equipment to test automated techniques for extracting terrain information.

Automated Extraction of Terrain Analysis Data

ETL scientists are working to automate the extraction of terrain analysis information from various types of imagery.

Researchers have already demonstrated automated techniques for extracting vegetation data from panchromatic photography. These techniques use image processing algorithms to identify grasslands and forests and calculate more detailed forest-related characteristics such as percent canopy cover and tree stem density.

Tree stem density is one of the factors which terrain analysts must consider in predicting cross-country mobility. Calculating tree stem density using manual photo interpretation techniques is a tedious procedure. Researchers have developed automated methods for identifying and counting tree crowns — and hence tree stems. They've compared stem counts obtained using these techniques with both ground truth data and manual photo interpretation counts. Tests showed that the new techniques hold considerable promise for making accurate tree stem calculations.

Efforts continue to refine the various data extraction techniques which have already been developed. Researchers are also working to identify automated techniques for extracting other features which are of interest to the terrain analyst.

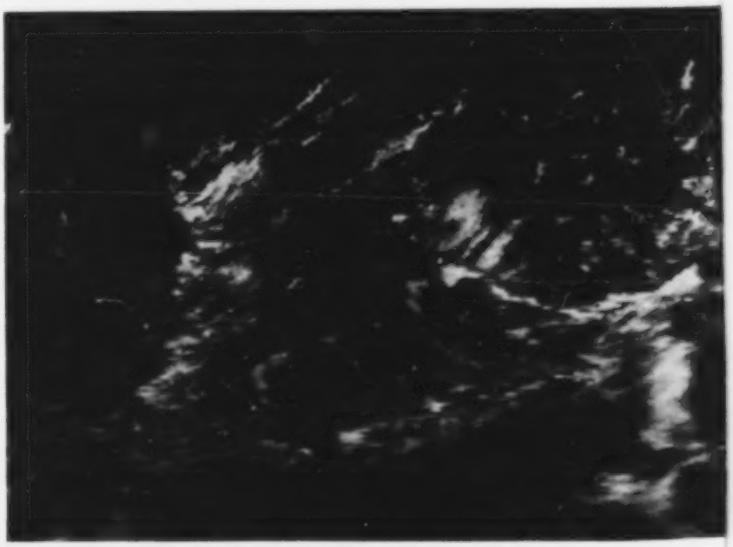
In the future, ETL scientists plan to test and perfect these techniques in-house. The Laboratories have purchased a special image processing system to support this work.

Researchers hope that these efforts will eventually pay off in the development of a fieldable interactive computer system for gathering terrain data. Such a system would help terrain analysts extract and combine geographic information from different sensors and data bases.

Landsat Study

For years, scientists have routinely used remotely sensed imagery to gather information in such fields as geography, geology, forestry, agriculture, hydrology and cartography. The limited resolution of early multispectral data, however, discouraged military applications.

Landsat IV and the thematic mapper sensor changed that. Launched in 1982, this platform and sensor provided greatly improved spatial and spectral resolutions. Data transmission from Landsat IV, however, was limited by poor relay links and data processing facilities; the system failed in 1983. Landsat V, which entered orbit in 1984, overcame the transmission difficulties experienced by its predecessor. Foreign concerns, such as France's SPOT IMAGE Corporation, also have sophisticated sensor systems in the works. As a result of these improvements, the Army and other military groups are now actively exploring ways to exploit multispectral information.



This perspective view was produced from terrain elevation data and land cover information derived from Landsat multispectral imagery.

ETL scientists began studying the use of multispectral and thematic mapper data in 1982. Their goal was to compare the accuracy of land cover information derived from multispectral and thematic mapper data and see if they could produce more realistic perspective views of the earth's surface by merging Landsat land cover information with DMA digital terrain elevation data. Multispectral scanner, thematic mapper, digital elevation and digital feature analysis data for test sites in northern Georgia were obtained and registered. Researchers evaluated the accuracy of the land cover information obtained from the two sensors and compared these data sets with the digital feature analysis data generated by DMA. Results showed a great deal of potential for the thematic mapper data. Three-dimensional perspective views were produced by combining the remotely sensed information with digital elevation data. Scientists arranged these scenes to give the viewer the impression of "flying through" the data. The "fly-through" software allows users to select a vantage point, vertically exaggerate features and add haze and other environmental effects.

ETL plans to follow up this initial Landsat study with an expanded investigation of the military applications of multispectral imagery. As part of this effort, scientists will establish a testbed for implementing algorithms which use multispectral data for such applications as tactical terrain graphic generation.

Future research efforts will include the development of improved graphic and perspective scene generation capabilities. By using state-of-the-art three-dimensional graphic terminals, scientists hope to increase the speed of graphic and perspective scene generation to near-real-time and identify the best structure for Landsat data bases. Researchers plan to install the refined Landsat perspective view software on the Terrain Analyst Work Station — an automated terrain analysis demonstrator described earlier in this chapter. Long-term plans call for incorporating Landsat graphic software into ETL's computer image generation facility (see "Spatial Data Integration and Display" entry in the "Basic Research" chapter).

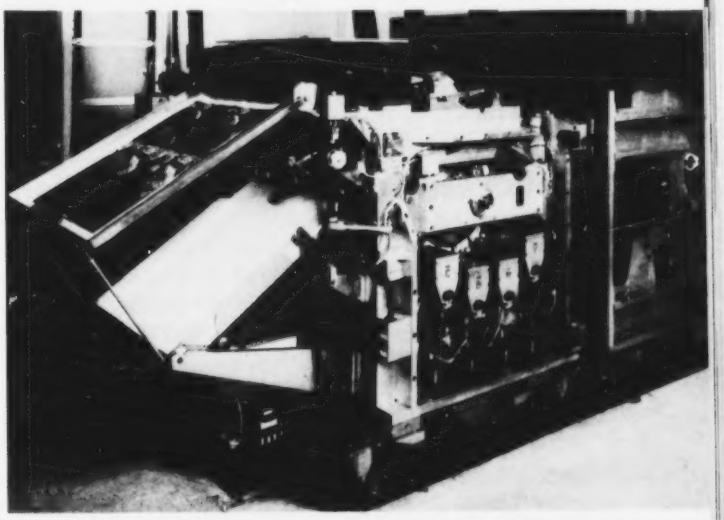
ETL's research in this area should eventually allow the Army to process and exploit remotely sensed data in the field. A rapid-response graphic generation capability will help analysts take advantage of multispectral data — data which may be the only or most up-to-date source of information available in crucial military situations.

Quick Response Multicolor Printer

Current Army topographic doctrine calls for a quick-reaction, combat-oriented, low-volume reproduction capability in the field. Topographic reproduction currently relies on offset lithographic presses — the same basic equipment that's been used by the Army since World War II.

These presses involve time-consuming platemaking and setup processes. While they can print large quantities of maps at reasonable cost, they are not suited for handling small runs of multicolor graphics and other special products. Nor can they provide the rapid print capability needed to support combat operations.

The Quick Response Multicolor Printer (QRMP) is designed to meet the combat commander's need for fast color copies of special maps and related products. This electrostatic color printer will eventually replace the lithographic printing processes which now provide direct support to topographic units in the field.



The Quick Response Multicolor Printer will give the Army fast, cost-effective reproduction support.

Unlike conventional lithographic presses, the QRMP employs a "dry" printing process similar to that found in commercial color copiers. These machines transfer dry color toners to paper via electrostatic charges. The QRMP, however, uses a laser scan of the original copy to achieve the color fidelity and high resolution needed for topographic products.

The QRMP will feature a variety of capabilities. The soldiers who man the printer will be able to:

Copy color or black-and-white originals as large as 24 × 30 inches.

Produce up to 75 multicolor or 225 monochrome copies per hour.

Overprint new information onto existing maps.

Print maps updated to show operations orders, order of battle or supplementary photographs as additions to the basic map.

Copy transparent overlays.

The printer will be mounted in a van or similar shelter.

In August 1980, ETL awarded a contract to the Xerox Corporation, Pasadena, Calif., for the fabrication of a prototype QRMP. Finished in December 1983, this advanced development (6.3) model completed Development Test I and Operational Test I in March 1985. Scientists hope to finish the engineering development (6.4) phase of the project and see the printer type-classified by 1989.

In conjunction with the 1980 advanced development model contract, Xerox also conducted a study on the feasibility of expanding the QRMP to include a digital printing capability. The study, sponsored by DMA, indicated that the printer could be modified to accept digital data as input. A preplanned product improvement will provide a digital interface for the QRMP in the 1990-1994 period. This interface will allow soldiers in the field to produce terrain graphics and other products from digital geographic data transmitted directly to the printer or recorded on tapes or disks.

Robotic Vehicle Terrain Navigation Subsystem

The Army is taking advantage of the relatively new technologies of artificial intelligence (AI) and robotics to develop unmanned robotic vehicle systems. These systems will consist of robotic platforms which carry such payloads as reconnaissance sensors or nuclear, biological and chemical detection/decontamination equipment. These intelligent machines will help keep soldiers out of potentially high-risk combat environments, providing the Army an important force multiplier.

ETL has been involved in AI/robotics research since 1981. In 1982, scientists began designing terrain navigation subsystems for the Army AI/robotics program.

A portion of this research thrust has evolved into the Army robotic vehicle program — a joint effort with the Defense Advanced Research Projects Agency which will be closely linked with the latter's autonomous vehicle research (see project entry in "Basic Research" chapter). With this program, the Army hopes to develop a near-term operational capability for unmanned robotic vehicles and eventually evolve this system into an autonomous robotic vehicle capability.

A management team which includes representatives from ETL, the Tank-Automotive Command, the Human Engineering Laboratory and the Armor Center has started working on a teleoperated near-term demonstration system. This first phase of the Army program will use existing technologies to assemble and test a remotely controlled demonstrator that has the same degree of mobility as a similarly constructed manned vehicle.

The planned demonstrator will consist of an unmanned platform, a command and control station and a non-line-of-sight communications link. Operators in the control station will plan the vehicle's route and pilot it across the terrain.

Navigation display screens will help operators in the control station plan the vehicle's route and pilot it across the "battlefield."

ETL is responsible for one of the demonstrator's major components — its terrain navigation subsystem. This subsystem, which can be adapted in principle to any platform, will allow a robotic vehicle to traverse battlefield terrain from a given starting point to a specific destination.

The subsystem will use navigation sensors, such as stereo vision, to provide real-time perception of the vehicle's immediate environment and a position/navigation device, such as an inertial navigation unit, to maintain a constant geographic reference. Operators will consult a global level route planner to select the "best" route for the vehicle to follow. In making course recommendations, the system's interactive route planning software will draw on *a priori* information about the area of operation — information stored in the form of digital terrain data bases. Operators will also have access to a variety of decisionmaking aids derived from these data bases. Shaded relief scenes, perspective views and graphics showing critical points (like bridges) and choke points (like narrow gaps between hills) will help them identify places along the route where adjustments might be needed.

In this first phase of the program, the robotic vehicle will still rely on human operators. A man in the control loop is a must if the demonstrator is to move and maneuver with the same mobility as an equivalent manned vehicle. Project officials, however, believe that they can gradually transfer the functions performed by the operators in the control station to the platform itself

— vehicle autonomy is their ultimate goal. This initial robotics project has been designed to facilitate such evolutionary follow-on development.

During this development process, the Army will be able to spin-off robotic systems equipped with specific payloads when they're needed. In this manner, the Army can field teleoperated robotic platforms in the near-term, more sophisticated semiautonomous robotic systems in the mid-term, and very sophisticated autonomous systems in the long-term.

Geographic Data for Civil Works Support

The Corps of Engineers manages millions of acres of federal lands and waterways. In recent years, Corps officials have begun using digital geographic information to plan and carry out their resource management responsibilities.

Conventional methods for producing this information are both costly and time-consuming. These factors limited the use of digital geographic data files in the past.

Recent developments in the research community have changed that. Improved analytical photogrammetric equipment (see project entry in the "Point Positioning and Geodesy" chapter) and computer-assisted data management and analysis techniques now make it possible to build and maintain high-quality digital data files on a timely and cost-effective basis.

In 1980, ETL scientists assembled a Computer-Assisted Photo Interpretation Research (CAPIR) facility to help specialists extract geographic information from aerial photographs (see project entry in the "Basic Research" chapter). CAPIR includes an Analytical Photogrammetric Processing System (APPS-IV), an *x,y* digitizing table and host computer.

Analysts can use the system to interpret imagery and make photogrammetric measurements with little or no photogrammetric training. CAPIR's extensive geographic information system software makes it easy for operators to enter, store, retrieve, manipulate and display the extracted data.

With the CAPIR facility, analysts can perform such operations as aerotriangulation, point positioning and mensuration. They can extract elevation data; determine slopes; create, update and edit geographic data bases; play back information using the system's graphic superpositioning capabilities; and conduct stereoscopic area searches.

Working under Corps sponsorship, ETL evaluated the use of APPS-IV/CAPIR technology for extracting geographic information and building civil works data bases. As part of this effort, scientists assessed the data base requirements of the civil works community to determine the most suitable Corps applications for CAPIR.

During the period between August 1981 and October 1983, the Laboratories conducted three pilot studies designed to demonstrate how CAPIR equipment and techniques could support Corps civil works and military program efforts.

In the Portland District, researchers used CAPIR to create digital data files for the lower part of the Columbia River. Recent dredging operations in this area have reshaped the shoreline, creating new wetlands and affecting vegetation and wildlife habitats in the region. Digital data files make it easier to monitor accretion and erosion rates and map historical changes in such areas.

In the Detroit District, scientists used CAPIR to extract topographic data needed to assess flood damage. Analysts compiled a data base containing structure and land use information for areas along the Clinton River. The Corps typically uses ground surveys to collect much of this information.

A third CAPIR demonstration project was conducted in the Seattle District. There the equipment was used to update the Fort Lewis Master Plan. At present, most of these plans exist as paper maps or mylar overlays; updating them is often a time-consuming and troublesome task. Working with CAPIR, scientists digitized the existing Fort Lewis information and then used the system's superpositioning capabilities to compare the old data with new aerial photographs. Analysts were able to detect changes and update the data base.

The Omaha District will be the first to integrate CAPIR technology into its standard operating program. The District has assembled a computer-linked APPS-IV workstation modeled on CAPIR. Officials plan to use this equipment to support the District's resource management and surveying programs. ETL scientists worked closely with District officials, providing technical advice on the purchase, installation and use of the workstation.

Researchers have prepared an "APPS-IV/CAPIR User Applications Guide" which will be published as a supplement to the Corps of Engineers Remote Sensing Manual. The guide provides operating instructions for the APPS-IV and describes how its geographic data collection and management capabilities can support Corps operations.

Contact: Geographic Sciences Laboratory

Environmental Effects

Since U.S. military commitments span the globe, the Army must be prepared to fight in almost every environment on earth. Tropical jungles, arctic tundras and hot, dry deserts are only a few of the hostile settings encountered in this global theatre of operations.

The Army must take the environment into account when it equips and trains its troops and when it designs and develops its materiel. The advent of increasingly sophisticated — and environmentally sensitive — weapon systems has made the identification and application of realistic environmental criteria an even more important part of the materiel acquisition process.

ETL's Geographic Sciences Laboratory identifies and publicizes the effects of environmental conditions on Army materiel. Lab scientists conduct basic research to study the characteristics and distribution of terrestrial environments. Applied research efforts relate environmental knowledge to the design, test, storage, issue and use of materiel.

ETL's environmental studies are aimed at improving materiel design criteria and upgrading the "tech base" of environmental effects information. Scientists are investigating the frequency and distribution of natural battlefield obscurants. They are creating computer programs and automated environmental data bases to support both materiel developers and combat commanders.

ETL researchers provide consultant services to Army agencies, helping them identify and interpret environmental guidelines governing the design, development and evaluation of Army materiel. They also review requirements documents to ensure that appropriate environmental standards have been included.

The Laboratories' environmental scientists represent the Army in a variety of international standardization activities. They help prepare documents that establish standard environmental criteria for use by the United States and its allies in designing and testing military materiel. They also coordinate the development and approval of these guidelines within the Department of Defense. Lab scientists have contributed to NATO Standardization Agreements and Quadripartite Standardization Agreements involving the United States, United Kingdom, Canada and Australia.

This chapter describes ETL's environmental research activities. ETL, of course, is not the only Army laboratory engaged in studying and solving environmental problems. The Army research community investigates terrain and climate conditions, atmospheric effects, battlefield-induced contaminants, background signatures, illumination and other aspects of the environment. The Corps of Engineers' AirLand Battlefield Environment (ALBE) thrust pulls these diverse efforts together into a comprehensive and coordinated attack — one which will help the Army master the environmental problems presented by the modern battlefield.

ETL is an active participant in this program. The projects described in this chapter and the preceding "Topographic Support" chapter contribute to the ALBE thrust. A description of this interagency effort concludes this chapter.

Materiel Design

Military equipment must work in many different climates and environments. Manufacturing "all-weather" materiel, however, can send development costs skyrocketing. The Army can't afford to make every piece of equipment capable of withstanding every "extreme" condition found on earth. Equipment must, however, be designed to function in the environments in which soldiers will most likely use it.

Environmental design criteria must reflect realistic battlefield conditions. Identifying appropriate guidelines for developing and testing Army materiel represents a major undertaking. ETL's environmental studies help the Army establish a rational basis for selecting environmental design criteria.

Laboratory efforts focus on developing improved methods for presenting meteorological, climatological and geographical data. Scientists, for example, have investigated new techniques for determining environmental stresses and transforming existing data. Researchers studied various methods of estimating heat exchanges and developed risk scenarios for climatic conditions which adversely affect materiel when they occur in certain combinations.

ETL scientists are presently developing methodologies for extrapolating critical climatological values for areas not covered by existing data. Working with available climatologies, researchers are establishing relationships between climate and terrain conditions found in known locations and mathematically applying the values obtained to parallel situations.

As part of this effort, they are assembling a degree-square climatic data base which will use information on 3,000 known stations to describe climatic conditions for almost all of the earth's land surface. To build this data base, scientists are using a regionalization system for degree squares and parts of degree squares, and an automated directory routine. They plan to identify representative stations for each degree square or portion thereof if significant regional differences occur within a square. Monthly statistics for 37 commonly reported climatic parameters will be entered for each representative station. Interpolative algorithms will provide data for areas where no representative stations are located. The resulting data base will supply useful climatological data for any locaton on the earth's land surface outside of Antarctica and the minor ocean islands.

Guidelines and Guidance

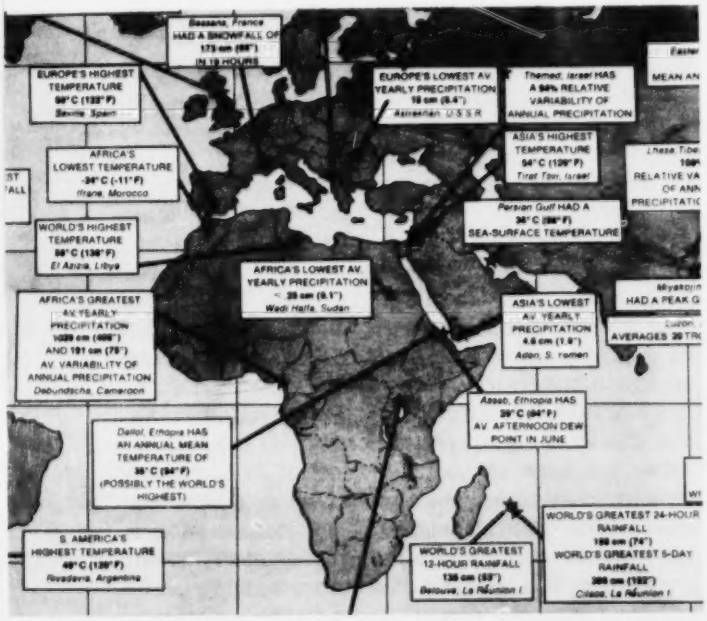
The people who work with environmental data and design criteria must understand the rationale for the values given and how these values should be applied to achieve valid and cost-effective results.

The military maintains a series of guidance documents to ensure that appropriate environmental standards are applied by those who develop, test and evaluate materiel. In 1984, ETL scientists began working on a revision of Army Regulation (AR) 70-38, *Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions*. The new regulation will update Army policy on the use of environmental considerations in systems design and address related issues raised by the realistic battlefield environment. Researchers are also revising those portions of MIL-STD-210C, *Climatic Extremes for Military Equipment*, which deal with Army concerns. The Air Force Geophysics Laboratory will incorporate this material in a new version of the standard.

The Army acquisition community consults these documents and other environmental data sources on a regular basis. Finding the appropriate information, however, can sometimes require a slow, time-consuming search.

ETL scientists have begun work on an automated environmental data system to support hardware designers and developers. This microcomputer-based Environmental Design Guidance and Evaluation (EDGE) system will contain interactive computer programs stocked with the type of information now found in AR 70-38, MIL-STD-210C and MIL-STD-810, *Environmental Guidelines and Test Methods*.

EDGE will give those responsible for the research, design, test and evaluation of Army materiel quick and easy access to environmental criteria and guidelines. A similar system has already been developed to support military planners and combat commanders. This Battlefield Environmental Effects Software is described later in this chapter.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Wadi Halfa, Sudan
ASIA'S HIGHEST TEMPERATURE
Tirat Tzvi, Israel
Persian Gulf HAD A SEA-SURFACE TEMPERATURE
ASIA'S LOWEST AV. YEARLY PRECIPITATION
Aden, S. Yemen
Asosa, Ethiopia HAS AV. AFTERNOON DEW POINT IN JUNE
Dallol, Ethiopia HAS AN ANNUAL MEAN TEMPERATURE OF (POSSIBLY THE WORLD'S HIGHEST)
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Weather extremes maps prepared by ETL serve as aids for establishing design criteria for military equipment.

Natural Obscurants

Many of the sophisticated combat systems planned for the future rely on electromagnetic energy propagation. Atmospheric conditions can severely degrade the performance of such systems. Natural obscurants like fog, haze, rain and dust and man-made contaminants like smoke and aerosols impair the effectiveness of electro-optical sensors. The "dirty" battlefield affects combat operations in other ways as well.

In the past, developers and planners all too often treated the environmental conditions typically found on the battlefield as unusual occurrences. To master modern combat, the Army must incorporate environmental factors in all parts of the materiel acquisition process. Technological trends in weapon and sensor design make obtaining information on environmental conditions that affect visibility (for both man and machine) a matter of increasing concern.

Before scientists can assess the impact of limited visibility on battlefield operations, they need to identify and quantify the environmental conditions involved. As part of the Army's effort to obtain this information, ETL scientists are studying the frequency and distribution of natural battlefield obscurants. Researchers plan to investigate the worldwide occurrence of atmospheric elements that reduce visibility and affect the performance of electro-optical sensors.

Initial studies focus on the frequency, type and distribution of fog as a potential battlefield obscurant. Fog, of course, creates a major barrier to visibility. It limits the operation of electro-optical sensors; hampers mobility, paradrop, incendiary bombing, chemical warfare and low-level reconnaissance; and affects target acquisition. Information on fog and its behavior can help battlefield commanders deal more effectively with its occurrence.

Researchers have completed a case study involving satellite observations of widespread fog. They analyzed satellite images of fog which covered a large portion of the eastern United States and monitored changes in visibility, temperature and air pressure which occurred during the fog's duration and dissipation. Use of satellite photographs allows observers to examine large horizontal areas of fog and detect relationships between fog and the terrain. The distribution

Scientists are investigating the frequency and distribution of fog as a potential battlefield obscurant.

of fog over the landscape in such photos tends to highlight certain features, making it easy to delineate mountains, valleys, coastlines and rivers.

Scientists will continue investigating fog and its role as a battlefield obscurant. They also plan to examine other natural obscurants including precipitation and the water content of the atmosphere.

Battlefield Environmental Effects Software

The Army research community has assembled large amounts of data concerning environmental conditions and their effect on combat operations. ETL's Battlefield Environmental Effects Software (BEES) takes advantage of these resources; it provides environmental characterization and effects information to support military planning. User-friendly BEES programs can help commanders and their staffs identify the conditions they'll face on the battlefield and predict how these conditions will affect military equipment, personnel and operations.

BEES pulls together many existing data bases and analytical equations. To assemble BEES, ETL scientists drew on the Laboratories' extensive collection of climatological data. They adapted special programs developed by other organizations for use with the system.

BEES gives the commander easy access to large amounts of environmental data. Soldiers today spend hours leafing through data books and climatological tables and making complex calculations to come up with the information that BEES can produce in seconds.

With BEES software, analysts can spend more time evaluating data and less time collecting and computing it. BEES subprograms fall into six functional areas. Some of the system's capabilities are described in more detail below.

Climatology: Four climatology subprograms cover geographical areas that are militarily and strategically important. These programs provide regional data bases that can help planners generate realistic battle scenarios, determine weapon and sensor performance and predict how environmental factors will affect mission success. A climatic statistics program, for example, contains 37 monthly environmental parameters for more than 225 specific locations. Users can consult other BEES climatologies to obtain information on prevailing wind speeds and directions, typical paradrop conditions and density altitudes.

Operations: Two BEES programs determine how existing environmental conditions will affect specific military operations. A real-time meteorological data/critical values program analyzes weather and terrain data provided by the operator and generates environmental effects information. In a few minutes, the computer determines the impact of the environment on such military activities as aviation missions; artillery operations; nuclear, chemical and biological warfare; aerial observation and photo reconnaissance; and weapon performance. Commanders can use this program to evaluate the impact of the environment on their troops, equipment and operations on a real-time, forecast and scenario basis. A second operations program computes density altitudes based on temperature, dew point and pressure data entered by the operator. The computer uses this information to determine the load carrying capacity for 14 helicopters currently found in the Army's inventory.

Cross-country mobility: This program uses a Defense Mapping Agency model to calculate the maximum off-road speeds for 12 friendly and threat vehicles. The user selects a vehicle from the program's menu and feeds the computer information on the slope, soil and vegetation found in the proposed area of operation. The program combines this information with the vehicle's performance specifications and prints out its off-road speed potential.

Engineering: Developed by the U.S. Army Construction Engineering Research Laboratory, this program identifies the manpower, time, materials and logistics support needed to carry out a variety of military engineering functions. It determines requirements for such operations as wire laying, minefield deployment, obstacle breaching and road demolition. It also classifies bridges with respect to their vehicle crossing and load capabilities.

Battlefield Environmental Effects Software assembled by ETL provides environmental information to support military planning and decisionmaking.

Almanac functions: BEES almanac programs compute sunrise and sunset times for locations between 60° N and 60° S latitude. They also determine when civil, nautical and astronomic twilight periods begin and end, and calculate moonrise, moonset and moon phase. These programs help commanders identify the amount of light available at specific times.

Utility packages: BEES utility programs can replace some of the reference manuals, texts and calculating techniques now used in the field. These software routines convert latitude and longitude readings into UTM coordinates (and reverse); determine standard pressures and elevations; and calculate aircraft altimeter settings for specific air pressure and elevation values. Other programs handle unit conversions and psychrometric calculations.

In 1983 and 1984, ETL scientists used BEES to support the Army's Gallant Knight training exercises at Fort Bragg, N.C. Researchers are translating the programs into the computer language used by the Army's MICROFIX system. BEES routines will be included as part of ETL's Terrain Analyst Work Station and Digital Topographic Support System (see project entries in the "Topographic Support" chapter). These programs will also play a part in the demonstrations planned as part of the ALBE effort.

AirLand Battlefield Environment Thrust

The AirLand Battlefield Environment (ALBE) thrust will give the Army the capabilities needed to measure, monitor and manipulate the battlefield environment.

Sponsored by the Corps of Engineers, ALBE provides a focus for the Army's environmental research and development activities. Organizations participating in this cooperative effort include ETL, the Waterways Experiment Station, Cold Regions Research and Engineering Laboratory, Atmospheric Sciences Laboratory, Chemical Research and Development Center, Army Materiel Systems Analysis Activity and Project Manager, Smoke/Obscurants.

The ALBE program will help the Army build equipment, train soldiers and develop strategies for fighting in the realistic battlefield environment. Researchers are identifying battlefield environmental conditions and developing models to predict their effect on military operations and weapon performance. This information will support materiel acquisition, training and doctrine activities.

The ALBE thrust will also help the Army keep track of the environment in the field. Many ALBE research efforts focus on providing improved intelligence support for the combat commander. Sensor technology and software programs developed by the participating laboratories will give field units an accurate up-to-date picture of the battlefield. ALBE computer programs predict how different terrain conditions affect helicopter operations and ground mobility. Other models can help commanders select targets, measure weapon performance, position sensors, defend against nuclear fallout and chemical contaminants, use smokes and obscurants, deploy minefields and make other tactical decisions.

Software programs developed under the Corps' AirLand Battlefield Environment thrust will recommend flight paths and altitudes for aviation missions.

ALBE officials plan to demonstrate these emerging environmental assessment techniques. This ALBE DEMO effort will put a variety of tactical decision aids to work during regularly scheduled training exercises.

The ALBE DEMO will focus on software capabilities. Two hardware systems — the Terrain Environmental Analysis System (TEAS) and the Tactical Environments Automated Measurements System (TEAMS) — will support the demonstration. Both demo vehicles are developmentally linked to environmental intelligence systems which will be used to support combat operations in the future.

TEAS will evolve from ETL's Terrain Analyst Work Station — a laboratory terrain data management system which uses state-of-the-art geographic information processing hardware and software to produce, update, revise and manipulate digital topographic data bases (see project entry in "Topographic Support" chapter). TEAS will incorporate terrain analysis and synthesis capabilities. Its resources will help units cope more effectively with whatever phenomena nature presents. They'll also be better equipped to deal with nuclear contaminants, chemicals, smokes, aerosols, biological agents and man-made weather.

TEAMS builds upon research performed by the Atmospheric Sciences Laboratory. It takes advantage of atmospheric sensors and data processing capabilities which have been developed for the planned Tactical Weather Intelligence System.

With the hardware resources of TEAS and TEAMS, soldiers participating in the ALBE DEMO will be able to update and revise terrain data bases and gather and process real-time information about atmospheric conditions. They'll use ALBE software programs to analyze terrain and atmospheric data and generate intelligence products.

In selecting software for the demo, planners looked for programs which promise near-term improvements for the environmental analysis systems (like the Digital Topographic Support System — DTSS) which will be in the field in the early '90s. The tactical decision aids produced during the ALBE exercises will deal with such concerns as mobility/countermobility, hazard zones, smoke obscuration, aviation flight planning and weapon system performance.

ALBE officials hope that the demonstration effort will help them expedite the fielding of these environmental analysis capabilities. If the demo proves a success, many of these software programs may be adopted as "product improvements" for DTSS and other Army environmental intelligence systems.

ETL scientists will help plan the ALBE DEMO. The Laboratories' environmental effects research and work in such areas as automated terrain analysis and computer-assisted photo interpretation support the overall ALBE program. As system developer for TEAS and DTSS, ETL will play an important role in preparing the demo and transferring ALBE hardware and software capabilities to the field.

Contact: Geographic Sciences Laboratory

Mapping

Keeping the military supplied with accurate, up-to-date topographic maps has never been easy. Cartographic techniques and equipment developed by ETL, however, have helped simplify and speed that complex job.

Map production, for example, depends on the extraction of information from remotely sensed imagery. Determining terrain elevation values from aerial photographs involves making extremely precise measurements. Until ETL scientists developed automated equipment to replace older procedures, mapmakers had to use mechanical devices (such as stereoviewers and stereoprojectors) to extract elevation data and draft terrain features.

Data extraction is only one of the many tedious, time-consuming tasks involved in making a map. Since the 1960s, scientists in ETL's Topographic Developments Laboratory have worked to automate such operations as map compilation, map symbolizing, cartographic drafting, editing and color separation. Many of the production techniques used today at the Defense Mapping Agency (DMA) owe their origins to this research.

ETL's mapping projects generally fall into two broad categories — automated compilation and automated cartography. This chapter describes the Laboratories' current work in both of these areas.

Automated Compilation

Data compilation is the first step in the mapmaking process. In the past, skilled specialists used photogrammetric instruments and manual measurement techniques to extract elevation and feature data from aerial photographs.

Computing elevation values from successive pairs of stereo photographs was perhaps the most time-consuming and difficult compilation task. Scientists studying ways to automate mapmaking focused on developing electro-mechanical aids to speed this measurement process. These mechanical systems, however, required highly uniform photography to produce satisfactory results.

To solve this problem, ETL scientists began working on a computer-controlled compilation instrument that could handle a wide variety of imagery. The resulting Universal Automatic Map Compilation Equipment (UNAMACE) scans pairs of stereo photographs and translates the electronic impulses produced into elevation data.

UNAMACE has been used to support military mapmaking since 1965. In the years which followed, ETL developed additional equipment for processing photographic imagery. Used together, these automated systems have transformed map compilation, cutting the cost and time needed for producing maps.

ETL scientists today continue to work on problems associated with map compilation. Much of this effort now focuses on developing ways to ensure the accuracy of digital data extraction. The project entries which follow describe some of this research.

Photogrammetric Technology Integration

Superpositioning provides an excellent way to verify digital elevation data. ETL scientists have exploited photogrammetric technology to provide DMA a softcopy superpositioning capability to support its automated elevation data extraction equipment.

Installed at DMA's Hydrographic/Topographic Center in 1983, this Elevation Data Edit Terminal (EDET) makes it easy for operators to detect errors in digital data and correct the information. EDET superimposes the extracted elevation data over the original aerial photographs. This softcopy display allows the operator to compare the digital data with the source imagery and make any changes needed to ensure its accuracy. The edited information can be used for map or data base production.

ETL scientists are using the digital data evaluation techniques developed for EDET as a basis for a comprehensive investigation of advanced photogrammetric technology. In 1984, an EDET system was installed at ETL where researchers have designed hardware and software enhancements for it. They've created a sophisticated Photogrammetric Technology Integration (PTI) testbed for use in supporting several DMA and Army projects.

Initial laboratory efforts will focus on a systematic quantitative and qualitative evaluation of the hardware and software enhancements which have been incor-

Scientists will use this testbed to investigate advanced photogrammetric techniques.

porated in the system. These studies will address the performance, precision, reliability and maintainability of the testbed.

After completing this "baseline" evaluation, scientists plan to explore potential applications of the system. In addition to use as a superpositioning system for evaluating and editing digital elevation data, the PTI testbed will provide the requisite hardware and software for testing new single-crystal CRT technology and evaluating digital feature data display algorithms and softcopy stereoviewing devices.

Project plans call for incorporating testbed enhancements into DMA's EDET system. Testbed research should result in improved operator editing capabilities for softcopy data bases. Researchers believe that the PTI system will prove an effective tool for producing targeting information and enhancing data bases used to support advanced weapon systems.

Multicolor Softcopy Display

Although much progress has been made of late in CRT technology, even the most advanced CRTs cannot provide the image size and resolution needed for large- format cartographic displays. Other display approaches exist, but most present major drawbacks in terms of cost, maintainability and facility requirements.

ETL scientists, however, are investigating new technologies that might yield the large-format, high-resolution, multicolor softcopy display capability needed by the cartographic community. As part of this effort, ETL will fund work on a new approach to flat panel displays — an approach which seeks to capitalize on the unique piezoelectric properties of stretched polyvinyldine flouride (PVF_2) film.

This project will be carried out under the Small Business Innovative Research program as a three-phase effort. Researchers will first study the specific physical properties of the thin film to ensure that it provides the desired qualities — easy fabrication, low cost, low power consumption, small volume and color capability.

If this feasibility study yields favorable results, ETL will let a Phase II contract for the construction of a prototype multicolor flat panel display. Successful testing of the completed equipment could eventually trigger a Phase III effort to incorporate this new display technology into existing government programs.

Extended Area Exit Pupil Viewer

Military photo interpreters today analyze more imagery in greater detail and shorter periods of time than ever before. Such demands make increased efficiency a must.

The photo interpretation process, however, relies on human beings — humans whose work will be affected by such factors as physical discomfort. Photo interpreters typically spend hours examining imagery with stereoscopes. The limited head motion allowed by these instruments causes eye strain, muscle aches and fatigue — all of which work against efficiency.

ETL scientists are investigating ways to alleviate this problem. An Extended Area Exit Pupil Viewer now under development may eliminate some of the physical discomfort involved in photo interpretation.

Designed to fit on stereoscopes currently used at DMA's production centers, this stereo viewing device increases the size of the instrument's exit pupil — the opening of the stereoscope's objective lens. With a viewer of this type, the operator would feel as if he were looking through a window of substantial size rather than straining to see through small eyepieces. The larger exit pupil should provide increased comfort and convenience — particularly if the photo interpreter must use the stereoscope for long periods of time.

In 1983, ETL awarded a contract for the production of a prototype model of the planned exit pupil viewer. Delivered to the Laboratories for testing in the summer of 1985, the device allows operators to view stereo images at distances varying from one-half to 1½ feet with a side-to-side motion of plus or minus one-half inch. This increased freedom of movement should ease the eye and back strain now experienced by many photo interpreters.

Filmstrip Verification System

For years, military aircraft have used projected map display systems to provide pilots navigation information. In the past, these systems relied on optical projection techniques and simple filmstrips made from existing maps and charts.

Recent advances in avionics display and control systems have been accompanied by similar improvements in map display technology. Today's systems offer better performance and increased versatility. Instead of optical projection techniques, they use electronic scanning devices to display map information on multipurpose CRTs.

Today's navigational filmstrips are also more sophisticated than their predecessors. Many contain up to five different chart scales and map out millions of miles. A single 60-foot 35mm filmstrip, for example, can cover 4.5 million square miles (an area greater than the continental United States) at a 1:2,000,000 scale and 2 million square miles at a 1:500,000 scale.

Pilots depend on these filmstrips for accurate map information; there is little margin for error in aircraft navigation. The extreme density of information portrayed on the filmstrips and the critical role they play make strict quality standards a necessity.

In the past, user groups and display manufacturers

kept tabs on the accuracy of navigational filmstrips. ETL scientists, however, are working on a new Filmstrip Verification System (FVS) that will allow DMA to take over this function.

Developed under contract, this equipment will feature special filmstrip transport and display capabilities. Using a computer to control the movement of the film, the FVS operator will simulate the positioning commands which drive the filmstrip display in the aircraft. The FVS will enlarge the film image and allow precise measurement of film position.

When completed, the FVS will be delivered to ETL for tests and evaluation.

Test Strategy for High-Resolution Image Scanners

Scientists working on this project designed a device-independent test strategy for evaluating the high-resolution image scanner planned for DMA's Advanced Image Digitizing System. The test plan considers such performance characteristics as geometrical accuracy, linearity of gray shade response, modulation transfer function and output resolution.

Although this project was a conceptual study, most of the procedures suggested have already proven their practical potential. Completed in 1983, the test strategy report was sent to DMA for use in evaluating the performance of image scanning systems.

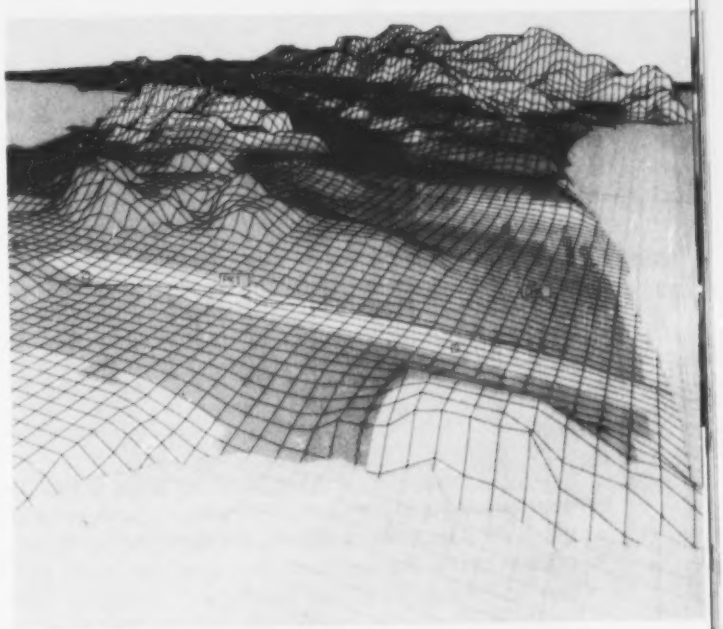
Automated Cartography

Compilation — the extraction of elevation and feature data from aerial photographs — represents the first part of the mapmaking process. The second part, cartography, involves drafting that information (contour lines, ground cover, waterways and man-made structures) onto a manuscript, preparing color separations and printing a final product.

Automated data extraction equipment developed by ETL made compilation quicker and easier. These improvements, however, also emphasized the need to automate the cartographic part of mapmaking.

In the past, skilled specialists identified terrain features and drafted them on maps. All features were drawn by hand with pen and ink — and painstaking care. Cartographers outlined man-made features (such as towns and boundary lines) on one sheet for printing in black. Ground contours were drawn on another sheet and printed in brown. Blue indicated water, green marked vegetation and red identified man's alteration of the landscape.

Scribing this information on paint-coated plastic sheets sped the production of color separations. Although this practice represented an advance, cartography remained tedious, repetitive and time-consuming. The advent of the digital computer, however, opened up the possibility of automating some of the cartographic tasks involved in mapmaking.



Over the years, researchers working in the area of automated cartography have developed a variety of software programs which use and manipulate digital map data. This experimental map of San Francisco was produced from digital elevation and feature data.

Over the past two decades, ETL scientists have reduced the amount of time and labor involved in map production. They designed hardware and software systems that convert visual images into electronic impulses. Computers use these impulses to drive machines that execute drafting tasks — tasks which were once done solely by hand.

As they worked on these automated systems, ETL scientists realized that the digital data which drove their drafting machines could also be used to produce new cartographic products. Current ETL research focuses on developing new editing techniques for digital map data and generating new products from that data — products created almost completely by computers.

Computer-Generated Terrain Displays

Many people find it difficult to visualize a three-dimensional surface represented in two dimensions. Maps, conventional aerial photographs and other forms of imagery used by the military all "flatten" the landscape. Contour lines may mark off changes in elevation, but even skilled map readers have trouble picturing the hills and valleys depicted by these lines.

In recent years, scientists have used automated cartographic techniques to produce three-dimensional terrain views — views which make it easy to visualize the actual lay of the land. Research in this area has focused on translating digital elevation data into shaded relief, elevation tints, oblique projections and perspective scenes.

ETL has developed computer programs that generate gray shades and line output for automatic plotters. Shaded relief can be added by calculating and plotting out gray shade reflectance values. Overprinting this information onto topographic maps provides a better visual impression of the terrain than can be obtained with contour lines alone.

Programs have also been developed to produce perspective views. These programs plot profiles of ground elevation points with vertical displacement. Automatic removal of lines which would be hidden behind intervening parts of the terrain improves the realism of the final product. The direction of the view can be changed by re-sorting the profile data. The resulting views give the map user an idea of how the land would look from a particular vantage point.

Scientists working with shaded relief, perspective views and other terrain enhancement techniques first concentrated on improving printed maps and graphics. Recent advances in computer technology, however, have set the stage for new applications that rely on CRT displays rather than paper products.

CRT capabilities and sophisticated interactive computer graphics techniques allow scientists to generate and display three-dimensional terrain views in a matter of minutes. The Laboratories' color graphics system, for example, can produce full-color perspective views with appropriate analytical hill shading in near-real-time. Researchers have also used a microcomputer to generate lower resolution perspective scenes.

Computer-generated terrain views have already been used at the U.S. Military Academy to teach cadets how to interpret and analyze the terrain. In the future, such graphics may help the Army map out battlefield maneuvers. A combat commander, for example, could study the terrain from his point of view and that of the enemy — and plan his course of action accordingly.

Computer programs translate digital elevation and feature data into three-dimensional views of the terrain.

Minicomputer Software for Terrain Elevation Data Modeling

Minicomputers provide an ideal tool for cartographic data processing systems. These inexpensive devices offer powerful capabilities for editing and manipulating data. They are easy to install and easy to operate; the cartographer can use the computer and supervise its processing functions without leaving his work area.

Cartographic minicomputers, however, need specialized software for processing map information. In 1980, ETL began work to develop computer algorithms to meet this need.

Laboratory efforts focused on designing programs to model terrain elevation data. Terrain elevation data consists of arrays of numbers, each of which corresponds to an elevation value. These values are measured at the nodes of a regularly spaced rectangular grid laid over a section of the earth's surface.

Scientists developed data modeling programs to handle specific interpolation tasks. These include:

- Converting elevation contour lines from 1:50,000 scale maps and other sources to a regularly spaced elevation grid or matrix where the grid spacing is usually much less than the contour interval;
- Converting a regular grid of elevation data to a contour map at any scale;
- Converting a grid of elevation data to a second grid with different grid spacing; and
- Smoothing and generalizing an elevation matrix so that when the smoothed matrix is contoured, the contours accurately represent the earth's surface at a scale much smaller than a 1:50,000 scale topographic map.

These computer programs are based in part on algorithms that iteratively derive elevation values using the mathematical techniques of spatial convolution filtering. The contour-to-grid conversion employs a 13-point biharmonic operator. The grid-to-contour and grid-to-grid interpolations use the Jancaitis and Akima algorithms, while the smoothing program relies on a combination of least squares, Laplacian, biharmonic and upper and lower control surfaces.

In 1983, this software was integrated into DMA's terrain elevation data processing systems; a DEM (digital elevation matrix) feathering algorithm was added in June of that year. These programs support DMA's Digital Landmass System and provide terrain elevation data for such weapon systems as the Cruise missile, Pershing II missile and FIREFINDER counterartillery radar.

Line Generalization and Feature Displacement Software

ETL scientists are investigating ways to automate line generalization and feature displacement — two map production processes traditionally performed by cartographers.

Both processes come into play when large scale maps are reduced and used as source materials for a smaller scale map. The cartographer must simplify the more detailed maps so that excess information will not clutter the new map and confuse the reader. Generalization is the process of smoothing the line work to eliminate insignificant twists and turns while retaining its overall character. Displacement involves separating features which may overlap as a result of the reduction.

Correct line generalization and feature displacement require the skills of a trained cartographer — one familiar with both the "look of the land" and the limitations of the graphic arts. ETL researchers have worked closely with DMA cartographers to define the essence of these processes. They have also examined existing automated techniques for generalizing and displacing data as well as methods for evaluating the results of these computerized operations.

With this study, ETL scientists identified seven methods of generalization which might be appropriate for use in a production environment. These include angle detection, mathematical fitting, epsilon filtering, low pass filtering, tolerance bands, point relaxation and digital elevation matrix smoothing.

Researchers also discovered that existing automatic feature displacement algorithms are not sufficiently developed to allow their use in actual map production. Techniques employed in circuit design, however, offer long-term potential in this area.

In the future, ETL scientists will begin testing the line generalization algorithms listed above to determine their utility for digital map production. Working with a research testbed, they plan to use the seven potential algorithms to generalize sample data sets containing aeronautical, hydrographic and topographic map and chart information. Feature displacement studies will concentrate on identifying overlap conflicts and developing interactive techniques to edit them.

These laboratory investigations will help researchers prepare design specifications for generalization and displacement software — software which can be used for map production at DMA.

Cartographic research focuses on the automation of various parts of the mapmaking process.

Raster to Vector Analysis

Digital cartographic data usually takes one of two forms. Raster data breaks an entire area down into individual picture elements or pixels, each of which is assigned some visual attribute (e.g., brightness or color). Vector data depicts particular map features by listing the *x*,*y* coordinates of their points and connecting the lines between them.

Each format offers advantages and disadvantages; both are of use to DMA and its mapping mission. At present, however, no good method exists for going from raster to vector format.

ETL scientists are examining raster-to-vector conversion techniques — techniques which would allow DMA to digitize analog map products using automatic raster scanning devices and convert the scanned data to raster format for editing. With this approach, a raster collection system would digitize paper maps or film separates; computer algorithms would then reformat the resulting raster data into a vector representation.

Researchers have developed a conceptual model which compares all facets of the analog-to-vector data capture process. This model includes:

Descriptions for pre-digitizing preparation;

Digitizing procedures for generating raster data;

Assignment of attributes to the digitized data;

Conversion of the data to a spatial referencing system; and

Entry of the resulting vector data into a data base.

Scientists have used this model to analyze DMA's current production methods and identify bottlenecks. The model also provides a tool for evaluating the digital data collection systems that are currently available at universities and in the commercial marketplace.

This survey of existing techniques will help ETL develop a benchmark testing package for evaluating new systems and software. Such an approach should allow researchers to examine proposed raster-to-vector algorithms in light of their impact on the overall data capture process — and determine which best meet DMA's needs.

Device Independent Graphics Software

Some computer graphics programs are designed for use with particular display systems. Graphics software which is "device independent," however, can run on any number of different display devices.

With device independence, a programmer can develop an application for the graphic display of mapping, charting and geodesy (MC&G) data using a softcopy device and have the application work with hardcopy devices. He can design the application without tailoring it to the display requirements of any particular graphics hardware system. Such built-in flexibility makes the software more adaptable and less likely to fall victim to device-based obsolescence.

ETL scientists are evaluating several of the methodologies for device independent graphics software (DIGS) that have been developed over the past 10 years. This effort involves testing DIGS packages in actual MC&G applications. ETL is also tracking the work of national and international organizations which are developing standards for device independent graphics software.

Mapping Applications of Video Disc Technology

Computer-linked video disc systems offer a powerful tool for displaying cartographic information. Such systems can support data archiving, navigation, training and military decisionmaking.

ETL scientists began studying the mapping applications of video disc technology in 1982. They assembled a testbed video disc system which features a laser optical video disc player interfaced with an 8-bit microcomputer. Both are connected to a television monitor which offers touch screen control and computer graphics overlay capabilities.

Researchers have used this equipment to demonstrate the military planning applications of video disc/computer systems. Software routines have been developed to exploit data storage, retrieval and display capabilities. A "map reconnaissance" program, for example, allows the user to display and study map images on the television monitor; he can pan across the map or zoom in for a closer view. Other programs allow the operator to position military symbols over the map backgrounds, creating situation maps and doctrinal templates.

Lab scientists are exploring these and other applications of video disc systems. They are also studying the design and production aspects of video disc technology.

In 1982, ETL joined with the U.S. Geological Survey and U.S. Army Engineer Water Resources Support Center to produce an experimental cartographic video disc. This disc contained a variety of mapping products, including Landsat imagery and aerial photographs as well as maps and charts. A graphic design study examined the present state of the art in cartographic video disc research and investigated human factors involved in perceiving and understanding information displayed on video disc systems.

ETL researchers are using the information derived from these projects to develop requirements and specifications for recording maps and cartographic information on video discs. A new study is planned to design map graphics suitable for video display.

ETL is also investigating future technologies important to cartographic video discs. An experimental hybrid disc, for example, is being produced to store both analog and digital mapping data. Scientists have acquired a microcomputer-controlled image digitizer for use in studying video signal processing and multigraphic overlaying. This hardware will be integrated into ETL's video disc system.

Researchers prepared special software to demonstrate the military planning applications of ETL's video disc system.

Electronic Transmission of MC&G Data

DMA has used the automated cartographic systems developed by the research community to create a variety of digital data bases. These data bases include cartographic information, such as planimetry, and textual information, such as the Notice to Mariners.

Those who use this information must have easy access to it. Several years ago, ETL was tasked to determine whether telecommunication systems could be used to transmit digital data to DMA customers with greater speed and efficiency. Scientists zeroed in on two particular DMA data bases — the Automated Air Facilities Information File (AAFIF) and the Automated Notice to Mariners (ANMS).

The AAFIF study indicated that an efficient telecommunication link could be developed for this data base using existing technology. DMA and AAFIF users, however, would need to modify their computers significantly to accommodate such a system.

The ANMS study yielded more promising results. This data base keeps Merchant Marine and Navy vessels posted on chart revisions and other factors that affect safe navigation. Researchers pointed out that electronic transmission would give ships at sea rapid access to this information. They recommended that a pilot program be undertaken to equip DMA's Hydrographic/Topographic Center with the telecommunication capabilities needed to test this data transmission approach.

As a result of this effort, ANMS customers can now use the public phone system (including AUTOVON) and TWX/Telex links to obtain up-to-date chart information. These telecommunication systems provide national, international and wartime service, transmitting ANMS data to ships at sea via the International Maritime Satellite System. A link to the Department of Defense AUTODIN system has also been established to serve Navy ships with access to the Fleet Satellite Communications System.

In 1985-89, researchers plan to develop a capability for transmitting 24 x 30-inch full-color graphic products via telecommunication networks to users worldwide within 24 hours.

The Advanced Edit System helps operators edit symbolized cartographic data.

Advanced Edit System

Producing a standard five-color topographic map is not an easy job. It takes hundreds of man-hours of work to draft the final symbolized overlays used to make lithographic press plates.

This final drafting is still done by hand. Using special cutting tools, cartographers scribe symbols onto specially coated drafting film. Compiled data (called the line manuscript) have already been photographically printed on this film. The line manuscript, however, contains only simple, unsymbolized feature information. It takes the skill of a trained cartographer to finish the job.

Computer-driven automatic digital plotters have been developed to take over this work. These machines can draft a map in only a few hours, providing both speed and accuracy. Computers can prepare the data needed to drive and control digital plotters. The data, however, must be edited to catch and correct mistakes introduced by imperfect computer symbolization routines.

ETL's Advanced Edit System (AES) was developed to handle this job. AES is an interactive graphics design system (IGDS) equipped with special interface software. This software permits AES to "read in" any of several DMA data and plotter formats from magnetic tape. The IGDS programs can then edit this information and produce corrected data and plotter files in the appropriate format.

AES was delivered to DMA's Aerospace Center in 1982. In 1983, researchers added graphic line symbolization software to the system; this software allows AES to convert centerline data to symbolized feature data. A second modification made in 1984 expanded the system to include text input/output editing capabilities.

Digital Pre-Press System

The Digital Pre-Press System (DIPPSY) links digital cartography and graphic arts production. As such, it will play a key role in DMA's all-digital map and chart production facility.

DIPPSY will translate digital cartographic data into a format that meets the processing needs of graphic arts production equipment. This equipment will use the data received from DIPPSY to produce screened and

unscreened negatives for conventional and simulated process lithographic printing.

DIPPSY may best be described as a cartographic image setter. In an all-digital environment, DIPPSY will symbolize digital cartographic point information, line features and raster data (e.g., shaded relief); handle polygon area fills; generate type; and compose this information to meet particular product specifications. The system, for example, would take feature data expressed in standard linear format (e.g., "road," "tower"), convert it to a raster format symbol in the proper color, and then transmit that symbol in compressed form to a hardcopy device.

DIPPSY will generate data in a variety of formats — formats that fit various production systems. One proposed hardcopy device, the FILMWRITER, will use data processed by DIPPSY to produce high-quality lithographic film images.

DIPPSY data files will support the production of maps as large as 44-by-60 inches with printed copy resolution of at least 1,000 lines per inch. The system will also provide raster image data that can be projected on softcopy devices such as the proposed Digital Map Color Proofer. This project, described below, will provide a softcopy display of DIPPSY data and serve as an editing device for data that will be reproduced in hardcopy form.

Digital Map Color Proofer

The printing industry uses color proofing to project how a final printed product will look. Printing control officials examine color proofs to decide if a job is ready to go to press. During press makeready, operators use color proofs as a guide, adjusting the press so that the printed product will match the proof.

The keys to color proofing are repeatability and acceptable representation of the printed colors. Several different methods are used today to produce color proofs. The development of electronic pre-press systems, however, dictates the need for an accurate, economical and fast digital color proofing system.

ETL is working on such a system for use in conjunction with DIPPSY (see project entry above). It will use digital data to produce an image for softcopy color proofing. The digital image data will be supplied, at least in part, by DIPPSY.

With a color proofing system of the type envisioned, electronic color processing could be carried out without going through all of the intermediate steps (such as film separations) which are now required. ETL scientists believe that softcopy color proofing will significantly reduce the time and costs involved in preparing and reviewing cartographic data.

FILMWRITER

The FILMWRITER is a high-speed, large-format film writing system. It will process compressed, raster-formatted digital data files and produce screened images on large-format lithographic film — and will do so with speed and precision.

FILMWRITER will serve as a hardcopy device for data produced by DIPPSY. It will, however, be controlled by its own computer and work on a stand-alone basis.

Plans call for the FILMWRITER to accept data from a variety of sources. Information will be fed to the system on high-density magnetic tape, magnetic disk and optical disk or via direct link with other graphic arts equipment.

FILMWRITER will decompress, screen and manipulate images. It will project data files as forward and reverse reading positives and negatives. The film images it produces will have a recording resolution of at least 1,800 lines per inch. FILMWRITER will also handle the processing functions needed to transfer cartographic line, symbol and type data onto film.

Contact: Mapping Developments Division, Topographic Developments Laboratory

Point Positioning

In the past, surveying was slow, tedious work. If a surveyor knew where he was in relation to a control point, he could identify unknown points. Doing so, however, meant conducting laborious cross-country surveys using transits, theodolites and other optical instruments; measuring distances with chains and tapes; and converting the data gathered into geographic coordinates.

Surveying has changed — so much so that a new term, "point positioning," has replaced the word "surveying" in the vocabulary of many topographers. ETL and its predecessor organizations helped develop the technologies that altered both the techniques and terminology of surveying.

During the '50s and '60s, scientists created a series of increasingly sophisticated electronic instruments for locating points on the earth's surface. These devices sped the surveying process and cut the amount of time and labor needed for most surveying jobs.

The inertial survey system was one of the most innovative of these devices. Scientists began studying the use of inertial technology in response to the Army's need for fast, accurate artillery surveys. Years of research in this area led to the development of the Position and Azimuth Determining System (PADS). Fielded in 1981, this device helps artillery crews position their weapons with speed and accuracy.

PADS represents only a first step in applying inertial technology to surveying. Researchers have developed inertial systems which measure horizontal and vertical coordinates with geodetic accuracies; determine gravity anomalies; and calculate gravity deflections of the vertical.

Scientists are also working on new inertial systems that provide three-axis measurements of vehicle attitude and attitude rates as well as position. Such devices will support electronic warfare, target acquisition and weapon systems.

ETL's surveying research has benefited both the military and civil works communities. This chapter describes the Laboratories' recent contributions in this area.

Position and Azimuth Determining System

The Position and Azimuth Determining System (PADS) cut hours off the time needed to "survey-in" gun and missile emplacements. Fielded in 1981, this self-contained inertial survey device provides position, elevation and azimuth data for artillery operations.

Like other inertial systems, PADS relies on guidance techniques which were originally developed for aircraft navigation. This palletized device can be mounted on jeeps, trucks or helicopters. It keeps track of its position while on the move.

PADS consists of an inertial measuring unit (a level platform equipped with gyroscopes and accelerometers), a control and display unit, a data processing unit and an independent power supply. Soldiers use a theodolite, tripod and target set to transfer azimuth references in and out of the inertial platform.

At the beginning of a mission, the PADS operator enters the coordinates of his starting point into the control and display unit. He then drives the vehicle to each point for which survey parameters are required. The inertial unit monitors the "forward-back," "right-left" and "up-down" motion of the vehicle. The data processing unit converts these measurements of motion into x,y,z coordinates which indicate the vehicle's position (x,y) and elevation (z).

PADS continuously calculates its change of position. After the vehicle stops, the system reads out position in UTM coordinates and elevation in meters — and does so in less than two minutes. Azimuth transfer can be completed in less than 15 minutes.

PADS allows the artillery surveyor to do much of his work from behind the wheel. He must stop periodically to adjust the system, performing "zero velocity updates." The PADS computer, however, automatically makes the necessary adjustments. A special software program called Kalman filtering estimates and corrects system errors. The surveyor can be on his way again in seconds.

During a six-hour mission, PADS can maintain a position accuracy of 20 meters CEP (circular error probable); an elevation accuracy of 10 meters PE (probable error); and azimuth accuracy to 1 mil RMS (root mean square). The system works in any type of weather at any time of day or night. It cannot be

Soldiers use ETL's Position and Azimuth Determining System to conduct artillery surveys.

detected by the enemy or deterred by electronic countermeasures.

PADS is accurate — and quick. Soldiers can now conduct artillery surveys almost 10 times faster than they could in the past. The system also reduces the number of men needed for survey jobs.

PADS was type-classified standard in March 1979. The Army let a production contract for 102 systems in July of that year. The first of these units reached the field in December 1981. A second production contract for 222 systems (plus options for 86 more) was awarded in July 1983.

ETL scientists continue to provide technical support for PADS procurement, production and fielding. In 1984, researchers investigated the feasibility of using new semiconductor technology to replace the PADS magnetic core memory. Memory replacement will increase memory reliability in fielded units by 50 percent and cut $1,000 off the price of each memory bought in future procurements. ETL also helped PADS users solve maintenance and vibration problems.

Advanced Inertial Surveying Equipment

ETL has explored a variety of applications for PADS-type inertial surveying equipment. Work with the Inertial Positioning System and Rapid Geodetic Survey System has resulted in improved surveying techniques for both the mapping and civil works communities.

The Inertial Positioning System (IPS) was developed for the Defense Mapping Agency (DMA). It provides quick position and elevation data for geodetic surveys. IPS consists of basic PADS-derived equipment. The use of selected inertial components and improved calibration and operating procedures helps the system achieve the higher accuracies needed for geodetic surveys.

IPS calculates horizontal position in map coordinates and elevation in meters. It can be used in conjunction with a conventional gravimeter to measure local variations in the earth's gravity field. The system records survey and gravity data on tapes for post-mission evaluation.

The Corps of Engineers tested a commercial version of the IPS for use in field surveying activities. Inertial techniques offer a fast, cost-effective alternative to traditional methods; they promise to help the Corps surveying program cut both costs and manpower requirements.

The Rapid Geodetic Survey System (RGSS) represents an upgraded version of the IPS. An improved computer program allows it to measure the major geodetic parameters — three-dimensional position, free air gravity anomalies and gravity deflections of the vertical.

The Position and Azimuth Determining System consists of (left to right) a palletized inertial reference and data processing unit, a power supply and a control and display unit.

Both the IPS and RGSS can be operated from trucks or helicopters. Like PADS, they must begin missions at known survey control points and must stop periodically to obtain zero velocity references. Both exceed PADS in accuracy; they measure horizontal positions to within less than one meter and azimuths to within 20 arc seconds.

ETL researchers continue working with these advanced inertial systems. They are using this equipment to develop, test and demonstrate new operating, calibration and data reduction techniques. Such techniques will help DMA determine position and gravity data for mobile missiles. Scientists are also studying applications related to airborne surveys and hydrographic surveys for the Corps' civil works program.

Technicians install the Rapid Geodetic Survey System in a helicopter for tests at White Sands Missile Range in New Mexico.

Measuring Deflection of the Vertical

Knowledge of the gravity field is important for strategic weapons. Conventional astronomic techniques for measuring deflections of the vertical (horizontal components of the gravity vector) are slow and labor-intensive. They also require clear visibility of the star field.

ETL has pioneered the use of inertial survey systems for interpolating the gravity vector between control points. Extensive tests have demonstrated that the Rapid Geodetic Survey System (see preceding entry) can effectively transfer and recover the gravity vector.

Scientists are working to improve existing inertial survey systems and develop advanced inertial systems and techniques for measuring deflections of the vertical. Researchers also hope to identify and demonstrate integrated approaches for recovering gravity vectors.

Modular Azimuth Position System

ETL scientists are working with the Project Manager-Cannon Artillery Weapons System to develop a standardized positioning/orientation device for a number of different weapon and target acquisition systems. Called the Dynamic Reference Unit (DRU), this device is part of the Army's Modular Azimuth Position System (MAPS) program.

The Army currently uses a variety of positioning devices to determine the location and orientation of its weapons and sensors. The MAPS program, however, will standardize this equipment, reducing the proliferation of positioning systems in the Army's inventory. This effort should help cut development, logistics and maintenance costs.

The DRU will provide an on-board inertial survey capability for mobile weapons and sensors. Scheduled for fielding in 1987, it will compute horizontal and vertical positions, attitudes (including measurements of grid azimuth, pitch and roll) and three-axis angular velocity.

The DRU will meet the survey requirements of such diverse systems as the M109/110 self-propelled howitzers, Patriot anti-aircraft missile and FIREFINDER counter-mortar/counter-artillery radars. Program officials have worked closely with system developers to ensure that the device meets the needs of as many users as possible.

In 1984, ETL scientists completed detailed technical specifications for the DRU. These specifications will serve as qualification standards for potential manufacturers. In September of that year, three engineering development contracts were let for the production of 27 prototype reference units. Qualification tests for these models are slated for spring 1986.

The M109 self-propelled howitzer is only one of the weapon systems which will be supported by the Modular Azimuth Position System.

MAPS program plans also call for the development of a Static Reference Unit (SRU). This device will determine azimuths for weapons and sensors which do not need the dynamic positioning capability provided by the DRU. Developmental work will begin after the Training and Doctrine Command finalizes a Required Operational Capability (ROC) document for the project.

Advanced Azimuth Technology

Before weapon and target acquisition systems can zero in on enemy targets, they must know their own orientation. Artillery crews generally use a weapon's azimuth with respect to north as the measure of its direction.

Several natural phenomena (stars, the earth's spin axis, etc.) provide a basis for azimuth determination. ETL researchers are investigating new ways to exploit these phenomena. This technology base project should help the Army improve the efficiency and timeliness of azimuth determination.

Magnetic compasses are often used to determine the direction of north. Although compass readings are easy to obtain, they are not accurate enough for many military applications.

Stars provide directional references for optical sightings. Soldiers must have precise time information and make complex computations to calculate azimuths from such observations. ETL scientists have developed a simplified technique for astronomic azimuth determination. The new technique uses a specially programmed hand-held calculator with built-in clock and a theodolite. With these instruments, soldiers can compute azimuths on site in a matter of seconds.

The spin axis of the earth points north; scientists have used this fact as a basis for azimuth determination. Gyrocompasses, for example, contain specially designed gyroscopes which sense the rotation vector

of the earth and provide direction references. High-accuracy gyroscopes, however, are expensive. These instruments are also susceptible to such disturbances as vehicle settling, wind buffeting and seismic vibrations. Researchers are studying ways to increase their motion tolerance.

As part of ETL's azimuth technology program, scientists monitor the state of the art in inertial instruments, looking for improvements in cost, size and reliability that might support weapon orientation. Researchers are investigating alternate sensor technologies such as fluidic gyroscopes and exploring different system mechanizations for solving tactical problems.

Interferometric or differential phase measurements can also be used to establish direction references. Such techniques rely on radio signals transmitted from sources at known locations. The Global Positioning System (GPS), a satellite-based radio navigation system, appears suited for this application. ETL scientists plan to examine the use of GPS signal receivers for weapon orientation.

Analytical Photogrammetric Positioning System

In 1971, the Lance Missile Program Office identified the need for a simple, rugged piece of equipment that could be used in the field to locate targets for the Lance tactical missile. The Analytical Photogrammetric Positioning System (APPS) was designed to meet that need.

Fielded in the fall of 1973, APPS features a data base of photographic materials and basic "off-the-shelf" hardware for making photogrammetric measurements. Soldiers use the system to determine the position and elevation of target points.

The Analytical Photogrammetric Positioning System has been used for target location and other survey jobs.

Successful development of the APPS set the stage for follow-on research efforts. In 1976, ETL scientists began work on a Product Improved APPS (PIAPPS) for the field artillery. Researchers replaced the system's calculator and substituted an American-made stereoviewer for the original foreign-made viewer. PIAPPS was type-classified in 1979; all APPS units in the Army's inventory have been converted to PIAPPS.

APPS provides point positioning accuracy comparable to that achieved with conventional ground surveys. The Navy and Air Force have bought APPS units for use in locating targets. The Defense Mapping School and Corps of Engineers are examining other survey applications for this equipment.

ETL scientists are working with more advanced analytical photogrammetric equipment. The APPS-IV (Analytical Photogrammetric Processing System) provides a basis for the Laboratories' Computer-Assisted Photo Interpretation Research (see project entry in "Basic Research" chapter). Scientists have also explored the use of analytical photogrammetric techniques for terrain data management and civil works applications (see "Topographic Support" chapter).

Monitoring Techniques for Dam Safety

During recent years, government officials and citizen groups have expressed growing concern about the safety and stability of the nation's dams. Surveying techniques developed by ETL help inspectors monitor dam safety. These techniques can also be applied to other large structures.

The standard way of surveying, alignment by triangulation, is not precise enough to detect small movements in large structures. Atmospheric conditions limit the accuracy of such measurements.

ETL scientists have devised a new way for surveyors to spot minute displacements in dams, locks and other large structures. This method uses standard distance measuring equipment, but substitutes trilateration techniques for triangulation.

Working with this method, surveyors measure the lengths of the sides of the triangle formed by two control points and a marker on the dam. The ratio of these lengths will remain the same even if changes in the atmosphere affect the actual distances measured. If the ratios vary when the measurements are repeated, the surveyor knows that the structure has moved.

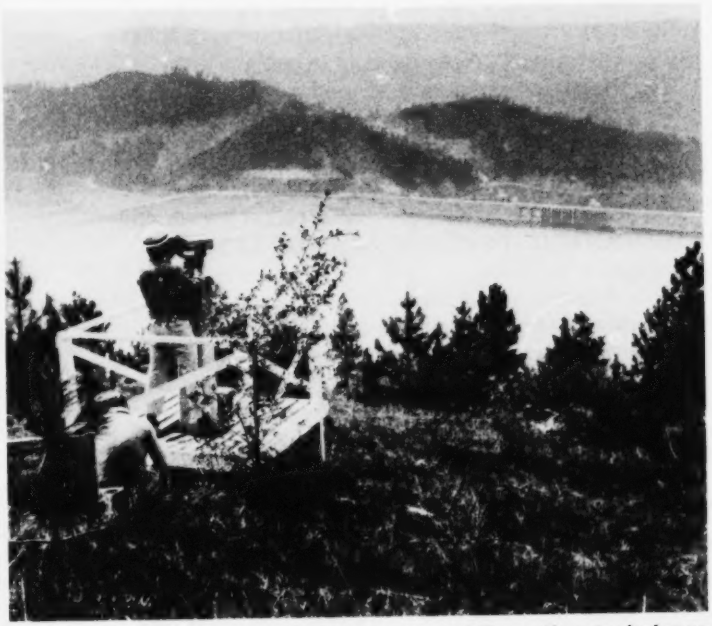
With distance measuring equipment and trilateration techniques, surveyors can make measurements that are accurate to within two to five millimeters — and can

do so in about five minutes. More than 20 Corps of Engineers districts are already using this method to monitor dams. It can also be applied to state dam inspection programs.

Trilateration techniques allow surveyors to measure lateral movement with speed and accuracy. Dam inspectors, however, must also keep track of the degree to which a structure tilts or bends under load.

Surveyors traditionally use plumb lines that are built into the structure to infer this information. These lines are very expensive (one can cost as much as $50,000) because they must be installed while the structure is being built. ETL scientists have developed a new way to measure tilt which is accurate, easy and relatively inexpensive.

The new method involves mounting small mirrors on the structure. If the structure tilts, the mirrors move along with it. Surveyors can use an automatic level fitted with an autocollimating eyepiece to detect small deflections of the mirrors and measure the degree of tilt.



The Corps of Engineers uses trilateration techniques developed by ETL to spot displacements in dams and locks.

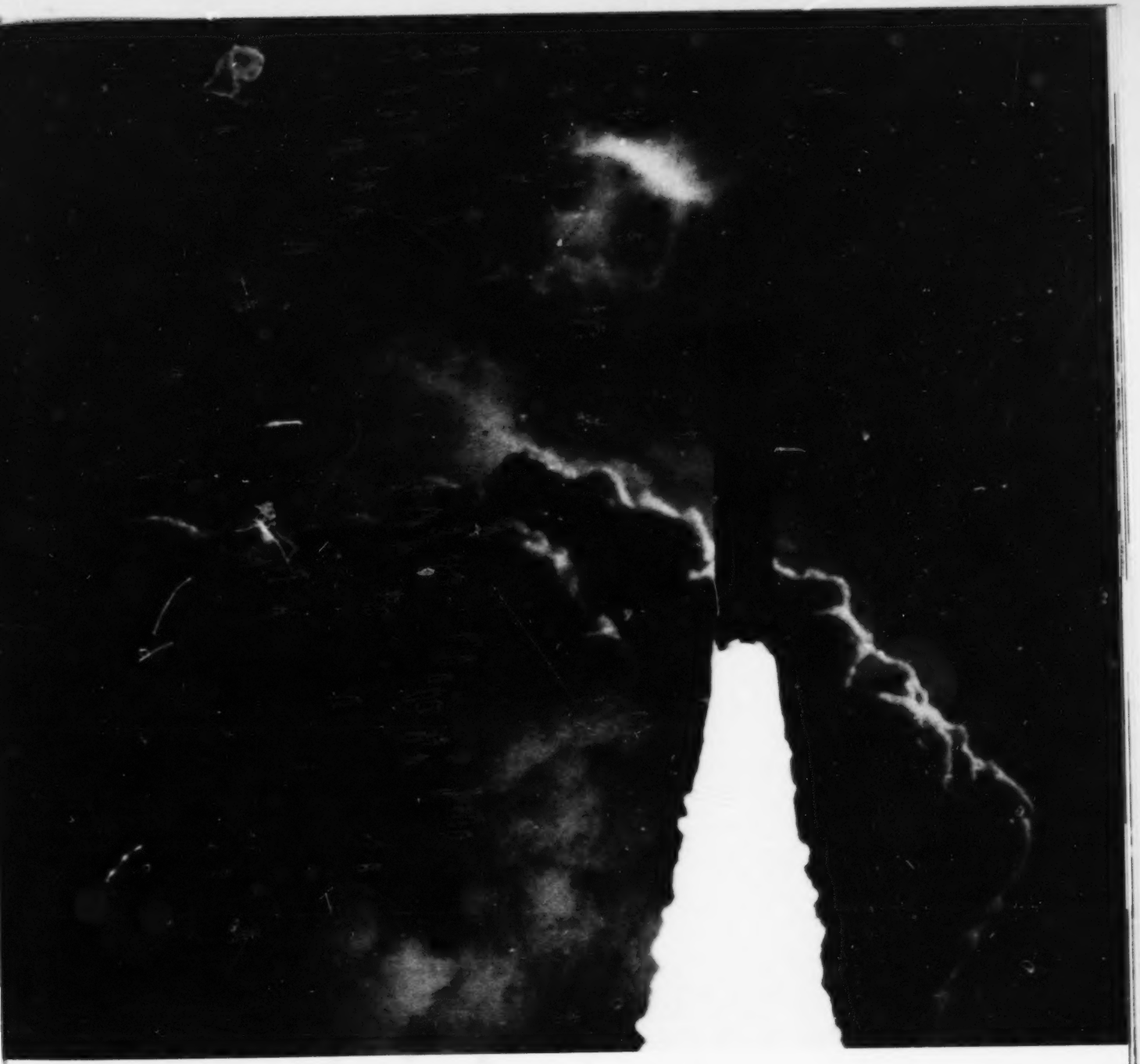
Mirrors mounted on the walls of a dam can help surveyors tell whether the structure is tilting.

Using this technique, surveyors can measure tilt with an accuracy of about two to three seconds of arc. Installation of the mirrors costs about $300; the surveying equipment needed can be bought and assembled for approximately $4,000.

The same equipment can be used to measure the tilt of lock walls during the fill-empty cycle. For this application, the mirror is mounted on a tripod and need not be permanently attached to the lock wall.

In 1984, ETL scientists began studying the possible use of satellite-based surveying equipment for continuous dam monitoring. The Laboratories' continued work in this area ensures that accurate, cost-effective techniques will be available for monitoring the safety and stability of dams and other large structures.

Contact: Surveying Division, Topographic Developments Laboratory



Weapon System Support

Many of ETL's research and development efforts directly or indirectly support the military's advanced weapon systems. Projects described in the "Point Positioning and Geodesy" chapter focus on investigating techniques and designing equipment to locate and orient weapons. ETL's Position and Azimuth Determining System, for example, is already being used in the field to conduct accurate, fast artillery surveys. An upgraded version of this system will measure geodetic parameters for sophisticated missiles. Scientists are also working on a standardized positioning/orientation device to support a number of different weapon and target acquisition systems.

ETL's environmental effects research contributes to the effective development and deployment of weapon systems. Environmental design criteria help materiel developers ensure that new systems will perform as expected on the battlefield. Environmental effects data bases will give commanders the information they need to predict how different battlefield conditions will affect weapon systems and decide how best to use the firepower at their disposal (see "Environmental Effects" chapter).

ETL is also involved in another major area of research which supports the nation's weapon systems — an area which involves the use of digital topographic data by "smart" weapons. Laboratory scientists, for example, helped evaluate and define the type of digital data which will be needed to support future Army systems (see "Data Base Evaluation" entry in "Topographic Support" chapter). Researchers are working to develop techniques and equipment which will make it easier for the Defense Mapping Agency (DMA) to produce the digital data bases required by advanced weapons, mission simulators, computerized command and control facilities and other military "customers." Laboratory studies aimed at automating feature extraction (see "Basic Research" chapter) and work with advanced photogrammetric technology (see "Mapping" chapter) provide only two examples of ETL's many efforts in this area.

ETL researchers have also worked on two specific — and successful — applications of digital topographic data for weapon system support. One of these projects represented a major contribution to the development of a terminal guidance system for a high-priority missile. On-going research in the area of weapon system guidance promises to yield increasingly accurate and reliable targeting techniques. The second application involved the use of digital elevation data to improve the fire support provided by a fielded Army tactical radar system. This chapter examines both of these projects.

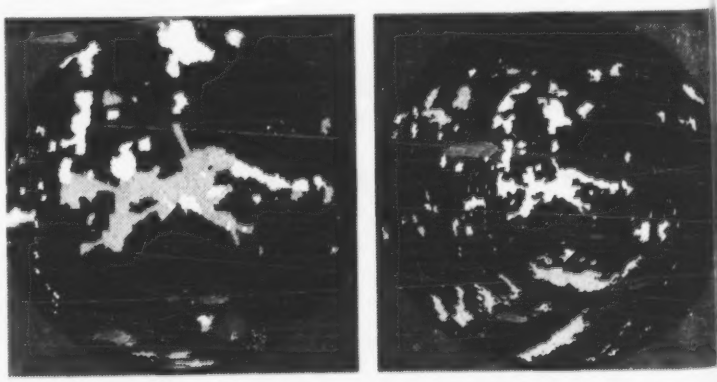
Weapon System Guidance Support

As the accuracy and reliability requirements for the U.S. missile force become more stringent, improved or new guidance techniques need to be explored and developed. Terminal correlation guidance techniques provide one method for obtaining the required accuracy and reliability. Correlation guidance technology, however, must be improved if it is to support the advanced weapon systems planned for the future.

Correlation guidance systems use simulated radar reference scenes to guide missiles to their targets. These reference scenes are produced from digital topographic data bases which contain elevation values and/or feature data. As the missile approaches its target, an on-board computer compares real-time radar imagery collected in-flight with a pre-generated reference scene of the target area. It correlates the two and calculates any adjustments needed to keep the missile on course.

Correlation guidance systems can bring the missile's warhead to within meters of the precise center of the target. During the last few seconds before impact, the correlation computer checks and corrects the missile's course many times. These guidance systems significantly improve missile accuracy; smaller warheads can be used and unintentional damage reduced. Missile launchers can be moved from location to location without degrading accuracy.

Because of ETL's experience in working with topographic data bases and computer processing techniques, the Laboratories played a major role in developing a terminal correlation guidance system for a high-priority missile system. ETL's responsibilities included designing computer equipment for producing reference scenes in the field. These van-mounted facilities allow soldiers to create scenes on site as



Terminal correlation guidance systems use simulated radar reference scenes to guide missiles to their targets. An on-board computer compares real-time radar imagery with these scenes and calculates any adjustments needed to keep the missile on course.

Computer equipment developed by ETL produces target reference scenes for a major Army missile system.

targets are identified.

Lab scientists helped DMA define, create and evaluate an operational data base for use in reference scene generation. ETL also developed a base plant reference scene production facility which allows DMA to manufacture reference scenes for preselected targets.

The data bases and processing techniques used to generate target reference scenes directly affect the accuracy and reliability of terminally guided weapon systems. ETL scientists continue to investigate data base development and reference scene production techniques. These studies are aimed at improving existing correlation guidance systems and supporting the development of more advanced systems.

As part of this exploratory development project, scientists are assembling a laboratory hardware/software system which will serve as an in-house testbed for data base and reference scene research. This facility will eventually allow ETL investigators to develop, manipulate, test and verify target data bases. They'll also be able to generate and modify synthetic reference scenes and simulate weapon system correlation models.

Researchers are analyzing existing and planned correlation guidance systems to identify the specific data bases and reference scene requirements associated with each. This study focuses on such concerns as content, accuracy and resolution. Scientists will use the requirements identified to design and conduct laboratory tests and experiments.

This work should eventually lead to the refinement of existing techniques and the development of improved data bases and reference scenes for weapon guidance. The Army, Air Force and Navy all stand to benefit from this research.

Contact: Special Projects Division, Topographic Developments Laboratory

Digital Elevation Data Dubbing Facility

The Digital Elevation Data Dubbing Facility (DEDDF) has been fielded at the U.S. Army Forces Command, Fort McPherson, Ga. Developed by ETL, this van-mounted computer facility represents the first successful tactical application of digital elevation data.

The DEDDF translates terrain data provided by DMA into a format that can be used by FIREFINDER — the Army's counterartillery and countermortar tactical radar system.

FIREFINDER back-plots enemy fire to its source and identifies the exact grid coordinates of enemy weapons. U.S. troops can then use this information to direct effective counterfire. Digital data supplied by the DEDDF will speed this process.

The DEDDF receives DMA elevation data recorded on commercial nine-track magnetic tapes. Soldiers check the data for errors, catalog the validated tapes and enter them into the system's master library. Each 100,000-meter grid zone is recorded on a master library tape; indexes for each zone are stored on a system disc. Operators can add, delete or change the information recorded on the master tapes.

When a FIREFINDER unit identifies an area for radar coverage, soldiers manning the dubbing facility extract the required data from the system. They reformat it for the desired grid resolution and record it on militarized magnetic tape cartridges. These cartridges, or "digital maps," are then dispatched to the field.

Using digital data, FIREFINDER units will be able to locate enemy gun positions with greater speed and accuracy. The DEDDF should help make effective counterbattery fire a reality.

Contact: Geographic Information Systems Division, Geographic Sciences Laboratory

Computer Sciences

During the past two decades, electronic and computer technology has transformed the nature of topographic research. The creation of a Computer Sciences Laboratory (CSL) at ETL was a byproduct of that revolution.

Established in 1968, CSL consists of three divisions, each of which concentrates on a different aspect of topographic systems research. The Information Sciences Division develops data management techniques and improved data structures for interactive digital mapping systems. Researchers in the Advanced Technology Division study a variety of topographic problems, investigating their impact on digital architecture and system software. The Systems Studies Division conducts concept studies related to Defense Mapping Agency (DMA) and Army digital image processing operations.

Digital Image Analysis Laboratory

The mapping community has historically relied on slow, tedious analog techniques to produce maps and charts for military operations. Hybrid techniques (like those described in the "Mapping" section of this book) have decreased the amount of time needed to create maps from aerial photos and improved the quality of the final product.

Purely digital techniques for mapmaking have been considered, but their cost-effectiveness has yet to be established. Such proof, when it does come, will be the product of a significant research program — one that has access to an extensive and powerful digital image processing system.

CSL scientists have assembled such a system. This Digital Image Analysis Laboratory (DIAL) supports a major research program in automated mapping and photo interpretation techniques.

DIAL features a unique mixture of hardware and software. Its major hardware components include two sequential computers; the STARAN array processor; an image digitizer and four real-time processing and display workstations. Two of these workstations were part of the original DIAL hardware configuration. The recent installation of a Vision One/20 digital image display system provided two additional workstations. This equipment is designed to handle very large arrays of digital images; its installation has expanded DIAL's image processing capabilities.

DIAL offers the photo interpreter a variety of image processing techniques — techniques which make it easier to extract terrain information from digital images. The system's capabilities include:

Scrolling: This search technique allows the analyst to view an entire scene on one screen while examining selected portions of the same scene on a second screen.

Magnification: The interpreter can enlarge parts of an image to see fine detail.

Rapid access: The analyst can display any stored imagery in a matter of seconds.

Colored terrain elevation: Images can be color coded according to elevation.

Colored contour mapping: The operator can color code contour lines.

ETL's Digital Image Analysis Laboratory supports research activities involving digital mapping and photo interpretation.

The acquisition of a Vision One/20 digital image display system significantly expanded ETL's image processing capabilities.

Transfer functions: This technique allows changes made in an image on the left screen of the workstation to be shown on the right screen.

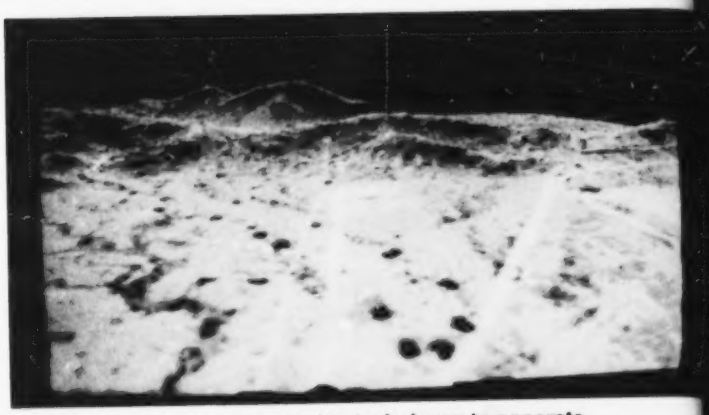
Gray level mapping: The analyst can manipulate the brightness and contrast of the gray shades in an image.

Photographic negative production: This process transforms a positive image into its negative.

Mosaicking: The photo interpreter can piece together many small images to create a single large one.

Change detection: This filtering technique shows where change has occurred between two scenes.

Warping: The analyst can geometrically alter or warp an image.



Scientists used image processing techniques to generate this perspective view from terrain elevation data.

Image Processing Research

In the spring of 1975, ETL and DMA began investigating digital image processing — studies which researchers believe will yield the next major step forward in automating the mapmaking process. Although DIAL and its image processing capabilities have not yet replaced conventional approaches to mapmaking, CSL scientists have demonstrated the feasibility of using digital techniques in stereo photo compilation and automated cartography.

DIAL, for example, includes a digital stereo compilation program called the Digital Interactive Mapping Program (DIMP). DIMP software allows the photo interpreter to extract elevation data from stereo pairs of digital images and produce highly accurate digital terrain matrices.

DIAL has also contributed to work involving automated cartography. The system's STARAN array processor allowed researchers to convert much of the automated cartography software related to raster processing to raster processing of digital images. On DIAL, raster processing is performed after the image has been processed by various mathematical functions — functions which detect edges and other features. Because digital images do not represent ideal data sets, these mathematical operations produce ambiguities, noise, unconnected lines and spurs. Interactive raster processing of these results with STARAN, however, removes these irregularities and creates a final product — a product which can be viewed immediately at a DIAL display station.

CSL's experimental work with DIAL has already contributed to the computer-based revolution in the world of mapmaking. The laboratory's future research will help continue that revolution.

Contact: Computer Sciences Laboratory

Basic Research

As late as 1960, the Army had no program for basic research in the topographic sciences. In that year, a research and analysis division was formed as part of the newly created U.S. Army Geodesy, Intelligence and Mapping Research and Development Agency — ETL's predecessor organization.

The Research Institute (as the division came to be called) conducts an ambitious program of basic and applied research. By exploring new areas of investigation and taking up new lines of inquiry, the Institute's scientists have helped ETL and the Department of Defense mapping and geodesy community stay abreast of the latest technologies — and take advantage of them. Their work provides the basis for the system-oriented projects undertaken by ETL's developmental laboratories.

In the past, the Research Institute devoted much of its resources to investigations involving geodesy and point positioning. These studies contributed to the advancement of geodetic theory and led to the development of improved surveying techniques and equipment. Although the Institute continues to conduct geodetic research, the major focus of its work has shifted considerably in the past decade. Today most of the Institute's scientists are working on problems involving the extraction of terrain information from different types of imagery.

The Research Institute consists of four centers, each of which pursues a different line of research in support of ETL's overall mission.

The **Center for Artificial Intelligence** studies methods and techniques for automating feature extraction. Established in 1982, the Center is applying the relatively new field of artificial intelligence to this area of investigation. Researchers hope to develop computer-aided techniques for analyzing aerial photographs. Other areas of study include robotic vehicle operations, image understanding and computer vision.

The **Center for the Physical Sciences** works to develop automated techniques for extracting information from radar imagery. This work involves the use of digital image processing, artificial intelligence, pattern recognition and computer vision. Scientists in the Center are also studying computer techniques for interpreting photos, integrating and displaying spatial data and generating terrain data bases.

The **Center for Remote Sensing** conducts research to determine relations between terrain properties and their recorded image patterns, spectral reflectance and emittance values. These studies support ETL's feature extraction and terrain analysis missions. Scientists identify terrain relations and establish photo interpretation routines that can be used to develop knowledge-based classification systems.

The **Center for Geodesy** develops theories, techniques and instruments related to gravity vector determination and point positioning. This work involves the use of astrogeodetic, inertial and gradiometric data. Scientists are also contributing to the development of a superconducting gravity gradiometer and investigating subterraneous mass detection and numerical weather prediction.

The Research Institute's major projects are described in this chapter. Projects are arranged by Center; organizational contacts are listed after the last entry for each Center.

Artificial Intelligence

Artificial intelligence (AI) is a branch of cognitive and computer science; it focuses on making computers perform tasks in a manner which resembles human thought. AI computer programs work with symbolic data and rely on relatively informal decisionmaking rules. They use inferential reasoning, logic and deduction to interpret information and solve problems — problems which in the past could only be solved by humans.

Scientists in ETL's Center for Artificial Intelligence are studying the application of this advanced computer technology to map production and image exploitation. At present, highly trained specialists perform this work. They examine aerial photographs and identify the landforms, vegetation and cultural features associated with the patterns in the imagery.

Attempts to automate these photo interpretation processes using traditional computer programs have met with little success. ETL researchers believe that ar-

Scientists are applying artificial intelligence to feature extraction and other military problems.

tificial intelligence can help them capture the expertise of the image analyst and program a computer to exercise it. They hope to develop semiautomated and automated techniques for pattern recognition and feature extraction.

In 1983, the Center acquired an in-house artificial intelligence testbed similar to one used by the Defense Advanced Research Projects Agency (DARPA) to study image understanding. Initial laboratory efforts focused on consolidating this equipment and retraining the Center's staff in the techniques of artificial intelligence.

These activities have laid the groundwork for the Center's AI research program. Scientists are working to develop methods and techniques which will support studies concerning the application of artificial intelligence to the "Intelligence Preparation of the Battlefield" processes and other aspects of battlefield management. This approach will also provide terrain descriptions for use in investigating model-based image understanding and map-guided scene analysis.

This test vehicle will be used to demonstrate increasingly sophisticated autonomous vehicle capabilities.

Autonomous Land Vehicle/Image Understanding

In 1983, DARPA launched a major research effort aimed at creating a new generation of "smart" machines for the military. This Strategic Computing Program will apply recent advances in artificial intelligence, computer science and microelectronics to military projects which require machine intelligence — projects such as an autonomous land vehicle.

Autonomous vehicles represent one of three specific military applications targeted by the program. Scientists are also working on a pilot's associate and an aircraft carrier battle management advisor. These projects will pull together work performed by government laboratories (including ETL), industry groups and university research centers.

ETL is serving as DARPA's agent for the autonomous vehicle program and for related research in image understanding. The Laboratories will administer and manage contractual work in these areas. ETL scientists will also perform in-house research to support the DARPA program.

The autonomous vehicle project focuses on developing the technologies needed to support robotic vehicle operations, not on designing an actual vehicle for military use. Working under ETL's technical supervision, an integrating contractor will coordinate vehicle-related research and conduct major technology demonstrations over a period of years. These demonstrations will put increasingly sophisticated autonomous vehicle capabilities to the test.

The vehicle completed the first of these demonstrations in May 1985. It used a TV camera and advanced image processing techniques to drive itself down a one kilometer stretch of road at a speed of 5 kilometers per hour.

In the future, the vehicle will take on more difficult terrain and travel at higher speeds. It will eventually master paved roads, desert surfaces and wooded terrain. It will recognize landmarks, avoid obstacles and replan its route when necessary.

Meeting these goals will depend in part on advances made in such areas as image understanding. Researchers working on this part of the DARPA program will focus on developing road-following capabilities and knowledge-based vision techniques. An unmanned vehicle will need to process large amounts of information at high speeds if it is to "see" and react in real time. Scientists will try to devise computer algorithms and architectures that can handle the quick, complex computations needed for machine vision. Results from these research efforts will be incorporated into the vehicle demonstration program as they become available.

Contact: Center for Artificial Intelligence, Research Institute

Computer-Assisted Photo Interpretation Research

ETL's Computer-Assisted Photo Interpretation Research (CAPIR) program focuses on developing improved techniques for creating and managing digital map data. As part of this effort, scientists assembled a computer-linked stereoscope for use in analyzing

high-resolution mapping and reconnaissance imagery.

ETL's CAPIR facility marked the first successful interface between the photo interpreter and a digital computer. The system provides a basis for the Laboratories' ongoing efforts to automate the photo interpretation process.

CAPIR combines analytical photogrammetric equipment, geographic information system software and automated data management techniques. On-line stereo digitization and superpositioning capabilities permit direct data entry and allow analysts to build geographic data bases directly from aerial photographs.

Using CAPIR, the photo interpreter can examine stereoscopic imagery and enter terrain information (expressed in three-dimensional geographic coordinates) into a data base. He can then display the newly digitized information in the working stereo model via superpositioning. The graphic feedback provided by superpositioning lets the analyst see the data base content as he creates it. He can also edit or verify existing data files by comparing the stored information directly with up-to-date photographs of the area of interest.

"On-line" photo interpretation makes it easier to compile terrain data bases from aerial imagery. CAPIR has created a new state of the art for digital mapping, providing new tools for validating, revising and intensifying terrain data bases.

ETL scientists have used CAPIR to test the application of computer-assisted photo interpretation techniques to military and civil works problems. Working with the system, researchers created a three-dimensional digital data base of Fort Belvoir from high-altitude mapping photographs provided by the National Aeronautics and Space Administration (NASA). Digital factor maps for landforms, hydrology, soils and land-cover have been used for digital cartography and specialized spatial analyses.

This special image processing system will be used to apply computer-assisted photo interpretation techniques to the analysis of softcopy imagery.

In one novel experiment, scientists used CAPIR to merge digital feature and elevation data into three-dimensional planimetric files. CAPIR's superpositioning capability allowed researchers to display these files in the stereo model and assess metric accuracy and cartographic generalization.

CAPIR technology has already been "handed off" to ETL's developmental laboratories. The Geographic Sciences Laboratory, for example, conducted a demonstration program which explored CAPIR's civil works applications. Computer-assisted photo interpretation techniques are being incorporated in the Terrain Analyst Work Station. (These efforts are described in the "Topographic Support" chapter.)

CAPIR technology has been transferred to other government agencies. The U.S. Fish and Wildlife Service, for example, acquired a CAPIR facility to support environmental studies. Scientists have used CAPIR to verify the accuracy of digital data files for the Defense Mapping Agency (DMA) and meet other military needs.

CAPIR continues to provide a major focus for feature extraction research. Scientists plan to improve the system's man-machine interface by integrating computer voice recognition and synthesis technology into the existing workstation. They are also working to develop a softcopy workstation based on analytical plotter technology. This expanded CAPIR facility will support the analysis and exploitation of digital imagery. Researchers also plan to introduce synthetic aperture radar models into CAPIR's geographic information system.

ETL's Computer-Assisted Photo Interpretation Research facility allows analysts to build geographic data bases directly from aerial photographs.

These developments will set the stage for more advanced feature extraction research. Scientists plan to use CAPIR to investigate image understanding techniques. Long-range goals call for the introduction of expert systems modules into the CAPIR environment. Such modules would transfer more of the work involved in photo interpretation from man to machine.

Rapid Preparation of Local Terrain Data Bases

Many of the Army's emerging weapon and tactical systems call for the use of digital terrain data. Innovative techniques will be needed to supply this information.

ETL scientists are investigating ways to generate and intensify local terrain data bases on demand. Working with digital mapping technology, hardware and software and an interdisciplinary approach, they hope to develop techniques for creating minimal terrain data sets in the field. These data bases would provide limited information about limited areas in response to immediate requirements. Researchers also plan to study methods for incrementally expanding and enhancing such "demand-driven" data sets.

Initial investigations have focused on defining general concepts for the rapid preparation of local terrain data bases. These concepts involve the use of online photo interpretation and digital spatial analysis.

Researchers will conduct case studies to evaluate these concepts. The studies planned will experiment with incremental data capture techniques. Scientists will start with sparse data sets for selected geographic areas and then systematically expand them into more detailed digital representations of the terrain. Experienced terrain analysts will use the Laboratories' computer-assisted photo interpretation equipment (see preceding entry) to study such related functions as rapid prototyping, critical evaluation and successive iteration.

Spatial Data Integration and Display

Computer image generation (CIG) uses computer algorithms and sophisticated processing techniques to produce realistic pictures of the terrain from digital data bases. Such pictures may play a part in the command, control and communications systems planned for the future.

The Army and DARPA plan to put CIG technology to work for the military. As part of this effort, ETL has started a new research project dealing with the integration and display of spatial data. These studies should lead to the next generation of digital map displays.

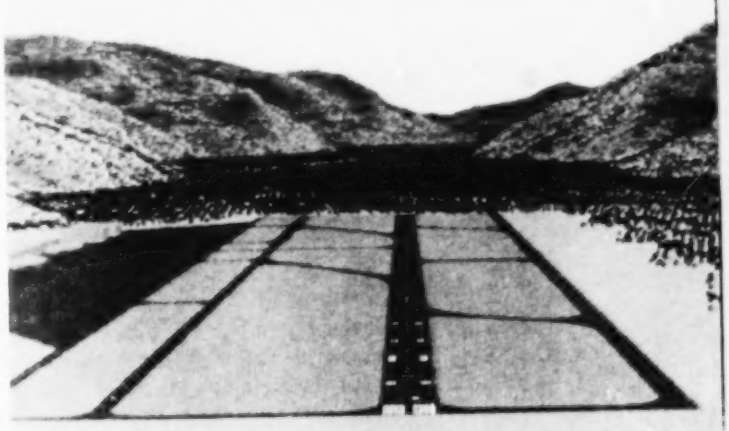
State-of-the-art CIG technology can already combine information from such sources as digital feature files, military maps, photographs, digital elevation data and satellite imagery to create pictures which are shaded, three-dimensional and perspectively correct. The resulting scenes depict the natural features of the terrain as well as such man-made objects as bridges and buildings. Clouds, fog and other weather effects provide added realism.

The technology used to generate these highly complex terrain scenes was developed under DARPA's Advanced Computer Image Generation Research program. Scientists working on Phase I of this project established the feasibility of a new approach to high-speed, high-complexity CIG. In Phase II, they designed, built and tested a working breadboard system based on the initial feasibility study.

This new CIG system uses a special depth buffer algorithm in conjunction with a pipelined/multiprocessor architecture. The depth buffer (a technique for determining how much of an object is visible from a particular viewpoint) allows the system to handle almost any type of data and generate highly detailed scenes. The multiprocessor architecture distributes the processing load and increases the speed of image production.

This basic design can support large CIG systems which work at real-time rates (30 frames per second) — systems of the type needed for realistic flight simulation. A similar configuration, however, can also be used as a basis for systems which are smaller, slower and cheaper.

The joint Army/DARPA program will apply the technology involved in such systems to specific military tasks. The U.S. Army Missile Command, for example,



Computer-generated terrain scenes may someday help commanders plan battlefield maneuvers. ETL scientists are investigating the use of computer image generation for mission planning and battlefield management.

plans to develop a CIG system to test guidance electronics and algorithms. ETL's portion of this Phase III research effort will address mission planning and battlefield management.

In 1986, a software-based CIG system will be installed at ETL; special-purpose hardware will be added the following year.

Scientists will use this laboratory testbed to perfect CIG techniques for merging and displaying terrain data. They hope to field advanced CIG capabilities as part of the later stages of the Digital Topographic Support System (see project entry in "Topographic Support" chapter).

Automated Radar Feature Extraction

The military currently relies on humans to extract terrain information from radar imagery. Such work is time-consuming, error-prone and costly.

Researchers in ETL's Center for the Physical Sciences are working to develop the technology that will lead to semiautomated and automated techniques for radar feature extraction. Such techniques should make interpreting radar imagery easier and less costly.

Scientists working on this project deal exclusively with digitized synthetic aperture radar imagery. They are investigating a variety of methods and techniques for processing this imagery — methods and techniques which should provide a baseline for future research. These techniques include digital image processing algorithms and transforms; the application of multiple order moments for measuring image texture; statistical and syntactic pattern recognition principles; well-proven computer vision techniques; and artificial intelligence/expert systems concepts.

Working with imagery of the Huntsville, Ala., and Elizabeth City, N.C., areas, researchers have developed feature vectors for such radar image categories as fields, water, forests and cities. They used more than 10 types of classifiers for categorizing image samples from the two areas.

Present research efforts focus on applying automated segmentation, region-growing and region-splitting techniques to large-scale (512-by-512 pixels) digitized radar images. Scientists are also studying the use of contextual information to classify image samples.

In the future, researchers hope to introduce higher level image processing techniques into this work unit. Such techniques would apply computer vision and artificial intelligence concepts to radar feature extraction.

Radar Exploitation Testbed

ETL's Radar Exploitation Testbed consists of image processing equipment, a host computer (which includes peripherals) and display devices. Researchers are using this equipment to test and validate algorithms, computer programs, methodologies and techniques for semiautomated and automated radar interpretation and exploitation.

Digital radar imagery recorded on tapes or disks provides the main "raw material" for the testbed. Scientists also have access to a digitized data base containing maps, aerial photographs and ground truth information. All of this data can be used interactively to analyze, interpret and exploit radar imagery.

The testbed's final capabilities will include image storage, screening, processing, displays, interactive overlays and machine intelligence. Scientists will use these capabilities to evaluate concepts, software and technologies developed both in-house and externally. Their work will include the use of knowledge bases, expert systems and image understanding techniques.

To be of use to the military, radar exploitation techniques must be able to handle large quantities of imagery with speed and accuracy. ETL's evaluation efforts will focus on these criteria. The interpretation and exploitation techniques under investigation will be applied to imagery with different data formats from different radar systems. Scientists will also address man-machine interface problems to ensure maximum efficiency.

Radar Signature Research

ETL's radar signature research focuses on the correlation of radar images with ground truth information. These correlation studies help scientists establish radar signatures for natural and man-made terrain features and prepare "descriptors" that characterize the radar images of these features. Researchers working in this area are also investigating the effect of radar system parameters and environmental factors on radar signatures.

As part of this effort, lab scientists are analyzing radar imagery from various geographic areas, paying particular attention to landforms, drainage patterns, vegetation, land use, transportation, surface materials and other militarily significant features. By studying these features as they appear in different geographic locations and different sets of imagery, researchers hope to identify the common image characteristics associated with each type of feature. The analysis of aerial photographs, maps and ground truth information supports these studies.

The Laboratories' Radar Image Analysis System (RIAS) has facilitated this research. The RIAS digitizes, processes and displays radar imagery. It consists of a computer (including tape and disk drives for storing imagery); a high-resolution video camera with analog-to-digital converter; a frame memory image analysis

Scientists use the Laboratories' Radar Image Analysis System to digitize, process and display radar imagery.

system; an image processor; two softcopy display units; and a plotter/printer.

This system allows researchers to digitize images, conduct statistical analyses, execute transforms, make mathematical computations, store and retrieve data and display results. Users, for example, can adjust radar imagery and aerial photographs or maps of an area to the same scale and orientation. They can display these materials separately or electronically superimpose them. This ability to compare radar imagery directly with other sources of information is particularly useful for analyzing radar signatures that cannot be classified automatically.

Scientists have used the RIAS to digitize and analyze high-resolution radar images of the Hudson River Valley and Elizabeth City, N.C., area. They have also completed a study on the effects of such radar system parameters as look angle, depression angle and impulse response on the detection and recognition of terrain features. Present efforts focus on the development of a set of radar descriptors for radar targets.

Contact: Center for the Physical Sciences, Research Institute

Indicators of Terrain Conditions — Manual Image Analysis

Scientists in the Center for Remote Sensing are working to establish relations between different terrain components and the patterns they display in different types of imagery.

Information on such relations can help the Army identify terrain conditions, locate potential groundwater sources and evaluate dust potential, cross-country movement and mobility. This research also supports the preparation of geographic data bases and tactical decision aids and may provide a basis for selecting subsurface waste disposal sites and making other terrain-related decisions.

The Center's work in this area involves cooperative studies with the U.S. Geological Survey (USGS), DMA's Inter American Geodetic Survey, the Pan Canal Commission and the Atomic Energy Research Establishment, Harwell, England.

These investigations combine different research techniques. Scientists draw on laboratory studies, field work and image analysis to gather information about terrain features and their interrelations. Manual techniques are used to examine aerial photographs, radar scenes and satellite imagery and link terrain components with their image patterns.

Proven pattern relations provide indicators of terrain identities (rocks, soil type, vegetation); terrain conditions and characteristics (dust potential, instability, canopy closure); and potential uses (waste disposal, groundwater, engineering materials).

Field studies help researchers establish relations that can be used to identify terrain features and predict terrain conditions.

ETL scientists are currently studying a variety of pattern relations. These include:

Landform, soil type and dust potential in subhumid areas;

Landform, soil texture and vegetation type in subhumid areas;

Surface conditions (including vegetation and soil) in subhumid regions and radar backscatter;

Fracture patterns and subsurface conditions in temperate zones;

Geologic structure, vegetation cover and radar patterns in tropical areas; and

Tropical closed tree canopy configuration and ground conditions, using aerial photographs and radar imagery.

These studies show usable relations between many of these factors. For example, landform, soil texture and vegetation type are so closely linked that, in many instances, if you know the identity of one, you can predict the other two. Scientists have also discovered direct links between vegetation, soil depth and type and surface irregularities (coppice dunes) and established relations between landform, grain size and fracture patterns for some igneous and metamorphic rocks.

Indicators of Terrain Conditions — Spectrophotometric, Chemical and Special Techniques

Spectral measurements can help the Army identify terrain materials and conditions, match and detect camouflage, establish terrain signatures, classify multispectral imagery and prepare data bases.

Scientists in the Center for Remote Sensing are studying the reflectance, absorptance, luminescence and radiance of natural and man-made materials. Combined with chemical analyses, these spectral measurements provide a basis for establishing relations that can be used to identify terrain features and predict terrain conditions. ETL investigators, for example, have studied relations between vegetation reflectance and mineralization and vegetation composition and microwave radiance.

This research combines both in-house and cooperative efforts. Participating organizations include the Camouflage Research Branch of the Belvoir Research and Development Center, U.S. Army Foreign Science and Technology Center, Naval Research Laboratory (NRL), NASA and USGS.

Scientists are working with laboratory and field measurements of pure samples and mixed fields of view. ETL researchers have made in-house spectrophotometric measurements from the ultraviolet region to about 50 micrometers in the infrared region of the electromagnetic spectrum. Visible and near-infrared field measurements have been collected at sites in Montana, Nevada, Utah, Arizona and Texas. USGS has provided luminescence measurements which cover the Fraunhofer lines within the ultraviolet, visible and near-infrared parts of the spectrum.

Researchers from ETL and the Department of Interior spread reflective material beneath a forest canopy at the Great Dismal Swamp. This test site was used to study the relation between vegetation structure and microwave radiance.

ETL scientists are also working with NRL to evaluate a jointly developed modified laser profilometer. They are testing the device over the Great Dismal Swamp (located along the Virginia/North Carolina border) to determine its effectiveness for measuring vegetation structure in relation to microwave radiance.

The Center's work with spectral measurements represents an ongoing commitment to basic research. Investigations in this area have already yielded significant results. These include:

Researchers have detected a luminescence mismatch between some man-made materials and some backgrounds. Such information may provide a basis for camouflage detection.

Scientists have collected spectral signatures for subhumid terrain surfaces. This data can support terrain identification and data base preparation.

The Center has measured the influence of weathering, lichen cover and desert varnish on the spectral reflectances of natural surfaces. Because these factors alter reflectance values, they must be taken into account in the development of terrain signatures.

Researchers have established usable relations between water absorption band characteristics and vegetation stress. This information could be used to predict the presence of groundwater.

The Center has developed an improved basis for the digital classification of subhumid Landsat scenes.

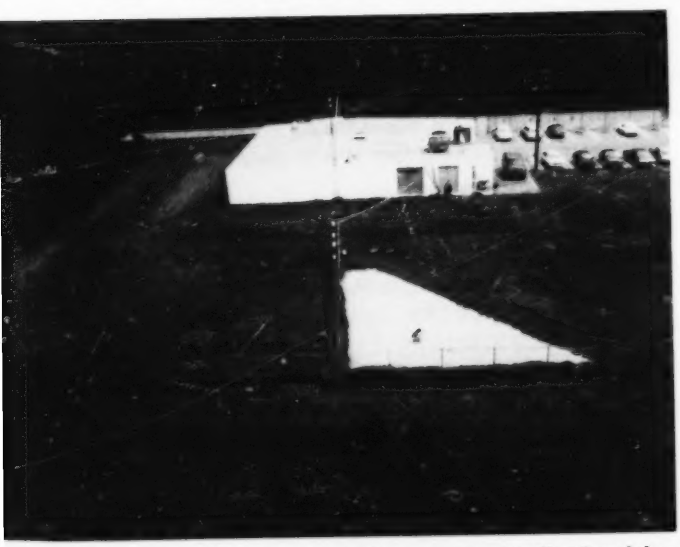
Radiation Backgrounds

ETL's radiation backgrounds research involves the study of thermal signatures and target/background contrasts. Scientists are measuring the infrared and microwave radiation characteristics of different terrain surfaces and man-made materials and examining how temperature, emissivity, time, season and weather affect these measurements.

The Army can use thermal signature and related information to identify soils, soil moisture and terrain surface characteristics. Research in this area also supports thermal modeling, camouflage detection and matching, image analysis and feature extraction.

The Center for Remote Sensing maintains an instrumented test site at ETL for use in thermal investigations. Cooperative studies with NASA, NRL, USGS, the U.S. Fish and Wildlife Service and the Camouflage Research Branch of the Belvoir Research and Development Center have helped the Center expand the scope of its research. Joint efforts, for example, have allowed ETL scientists to conduct field studies at the Great Dismal Swamp National Wildlife Refuge, Va./N.C., and Merchants Millpond, N.C.

Scientists working with thermal signatures and contrasts must take many different factors into account. The absorption and emission of electromagnetic



ETL's instrumented test site supports studies involving thermal signatures and target/background contrasts.

The three trees shown in this thermal image provided surface targets for a laboratory study involving radiant temperatures.

energy takes place in a relatively thin layer — micrometers for infrared frequencies and millimeters for microwave frequencies. As a result, surface radiation patterns will be influenced by events from below (thermal conductivity) and above (wind, rain, changes in air pressure, incoming radiation, haze).

Different materials heat and cool at different rates; their thermal signatures and contrasts will vary daily as well as seasonally. A small pond, for example, may appear hotter than its background early at night, match the background in the middle of the night, and be cooler than the background late at night.

ETL researchers have examined some of these relations. Scientists have used the Laboratories' instrumented test site to study the effects of time, season and weather on the thermal signatures of bare soil and different types of ground cover. They've also tested various materials and targets against different backgrounds.

Measurements made at the site include air temperature, soil temperature and soil moisture profiles; incoming and outgoing radiation; and wind speed and direction. The information gathered provides a standard data set that can be used to develop mathematical models for time-varying thermal signatures. Scientists can also use the data to make predictions about times and conditions for maximum or minimum thermal contrast between a target and its background.

Field studies at the Great Dismal Swamp and Mer-

chants Millpond have focused on evaluating airborne remote sensing techniques and target sensors. Researchers use "ground truth" information on soils, moisture, vegetation and weather to study thermal measurements and establish relations that provide a basis for predicting terrain characteristics. They are also testing the ability of sensors to distinguish specific targets against different backgrounds.

Scientists working on these projects have identified some of the meteorological and ground characteristics associated with the changes in thermal contrast which occur at different times and different seasons. They've learned that incoming long wave radiation is the most important piece of information needed to predict thermal contrast. Research results have also suggested a possible relation between microwave brightness and vegetation type and provided a basis for understanding why certain targets are so easily confused.

Photo Interpretation Logic and Feature Extraction

The Center for Remote Sensing has documented selected results from the research efforts described above. This documentation can help the Army and other agencies gather and interpret terrain information. The materials assembled support terrain analysis work, data base preparation, and camouflage matching and detection. They also provide a basis for developing image keys, knowledge-based systems and digital classification techniques.

One major documentation effort involves the preparation of single sheet summaries for photo interpretation. These sheets identify specific air photo patterns that are direct indicators of terrain conditions and materials. Topics dealt with include rock, soil and vegetation type; potential for dust generation; effects of surface irregularities on mobility and cross-country movement; areas of instability; and location of engineering materials.

Scientists have completed 70 of the Air Photo Indicator sheets. They have also prepared a series of spectral data sheets. These sheets link measurements of reflection, luminescence and radiance to specific terrain identities, conditions and camouflage signatures.

In addition to the summary sheets, researchers have developed a knowledge-based example of a photo interpretation routine and soil classification and vegetation classification systems based on photo patterns. They have also reviewed 20 published land cover/land use classification systems.

In September 1984, the Center cosponsored a workshop on desert processes with the USGS Desert Studies Group. Scientists from government agencies and universities discussed such subjects as aeolian/fluvial processes, desertification, potential for dust generation, analogous areas concepts, potential photo indicators and data base requirements. These discussions provided a basis for new cooperative research efforts — efforts which may yield information for photo interpretation and feature extraction.

Contact: Center for Remote Sensing, Research Institute

Geodetic Research

Geodesy is the science of determining the shape and size of the earth, the exact position of points on its surface and variations in its gravity. Such information is important for modern weapon systems and other military applications.

Scientists in the Center for Geodesy are conducting basic research and exploratory development in this field. Their work is aimed at supporting the development of new geodetic techniques and instruments for the military. Current areas of investigation include:

Astrogeodetic-inertial gravity vector determination: Scientists hope to develop astrogeodetic-inertial techniques for determining gravity vectors — techniques which can be used with both single and multiple traverses. This kind of gravity vector determination supports the construction of local and regional fields of gravity anomalies and vertical deflections which are proportional to the horizontal derivatives of the anomalous gravity potential. This surface information allows analytical upward continuation of the three gravity components.

Optimal and quasi-optimal positioning: The Center is studying ways to achieve optimal and quasi-optimal positioning including a gravity-programmed inertial positioning system — ways which avoid the data constraints imposed by Kalman filtering and achieve greater accuracy. Kalman filtering exploits only one data set at each vehicle stop where measurements are made.

Gravity gradiometry: Research in this area addresses the post-mission adjustment for the Bell gravity gradiometer. Scientists are also working to develop an improved method for using Bell gradiometer measurements to determine vertical deflections above rough mountainous terrain.

Astronomic positioning: A fourth major research effort focuses on developing improved techniques for astronomic positioning in the field. Scientists are also looking at new ways to determine the corresponding astrogeodetic vertical deflections. This work includes the examination of European techniques and equipment.

Superconducting gravity gradiometer: Scientists are working to develop electronic control in support of the superconducting gravity gradiometer. This instrument was designed for NASA by researchers at the University of Maryland. Related ETL research focuses on platform development and error control. Techniques and strategies for subterraneous mass detection will also be developed.

In addition to these geodetic research projects, the Center is also studying numerical weather prediction and its potential Army applications. As part of this effort, researchers will examine initialization of meteorological fields, dynamic prediction models and nested grid models. They will also look at such matters as densification of observation stations and the generation and use of three-dimensional digital weather data.

Contact: Center for Geodesy, Research Institute

Terrain Analysis Center

Military planners have always needed accurate, timely information about the terrain. One lesson learned from the 1973 Middle East war was that the Army had only limited capabilities for producing this information.

At that time, the Defense Intelligence Agency (DIA) was responsible for providing the services with military geographic information. DIA, however, did not have the resources needed to meet the Army's expanding terrain analysis requirements. In 1975, the Terrain Analysis Center (TAC) was formed at ETL to provide the information needed.

Today, TAC prepares terrain studies in response to the requirements of a broad range of Army elements. Unlike ETL's other units, TAC has an operational rather than a research and development mission. Its work contributes to the Department of the Army Consolidated Topographic Support Program. The Assistant Chief of Staff for Intelligence validates TAC's terrain analysis program and sets its priorities; the Chief of Engineers funds its work.

The Terrain Analysis Center maintains a data management capability for worldwide geographic information.

TAC Mission

Three documents provide the authority and official framework for TAC's mission:

Chief of Staff Memorandum, *Army Departmental Terrain Analysis Requirements Processing*, February 24, 1977;

AR 115-11, *Army Topography*, December 1, 1977; and

DOD Directive 4705.1, *Management of Land-based Water Resources in Support of Contingency Operations*, October 11, 1983.

Working under these guidelines, TAC keeps the military supplied with accurate, timely information about the terrain. Specifically, the Center's analysts:

Prepare data bases of terrain conditions to support strategic and tactical contingency requirements;

Evaluate terrain and cultural data to determine their potential impact on military operations;

Collect and produce land-based water resources information in support of worldwide military hydrology requirements;

Maintain an Army Central Terrain Intelligence File to support field source data requirements;

Provide technical guidance and advice to terrain teams in the field;

Produce special studies for unique Army terrain analysis requirements; and

Maintain a quick-response capability for crisis support.

TAC also makes a unique contribution to ETL's research and development work. Much of that work focuses on developing improved techniques and equipment for extracting and analyzing terrain information. The co-location of TAC with ETL's research laboratories facilitates close interaction between developer and user. Through its production work, the Center identifies problems which need to be addressed by the research community. It also serves as a testing ground for new techniques and equipment as they emerge from the laboratories.

TAC Products

The terrain analyses produced by TAC include both graphic and narrative material; their format and content vary according to the user's needs. Most, however, involve the same basic data collection and analysis procedures.

To prepare a typical terrain study, analysts must first assemble basic information about the geographic area involved. They consider such natural elements as surface configuration, soils, geology, vegetation, drainage, surface water, groundwater and climate. They also identify cultural or man-made features such as built-up areas, highways, roads, railroads, pipelines, ports, harbors, airfields, electric power lines and water storage facilities.

After analysts compile this basic data, they then

prepare the evaluative portion of the study. By combining the information gathered on natural and cultural features, they identify the availability of cover and concealment for troops and equipment; assess cross-country mobility; map out landing and drop zones; and determine possible avenues of approach. Other evaluative topics include line-of-sight, key terrain and state-of-ground analyses.

Over the years, TAC has produced strategic and tactical terrain studies, Army Intelligence Surveys, planning analyses, training products, hydrologic information and bibliographies. Analysts have prepared special studies on military operations in built-up areas, maneuverability and flooding. They have also completed analyses on many U.S. military installations.

Current Program

The Center's top priority project involves preparing Army Intelligence Surveys for the Army Intelligence and Security Command. These comprehensive strategic level planning studies focus on the worldwide distribution of natural and man-made resources.

TAC devotes a considerable amount of effort to the DOD Terrain Analysis Program. Analysts are compiling 1:250,000 scale Planning Terrain Analysis Data Base graphics which feature six thematic presentations per map sheet. Managed by DMA, this joint DMA/TAC project has been designed to meet the terrain information requirements generated by the Unified and Specified Commands, military departments and DOD agencies.

Analysts use aerial photographs and other source materials to identify terrain features and evaluate their effect on military operations.

TAC also maintains the Army Central Terrain Intelligence File, providing field commanders with reliable, timely information about the terrain as well as technical advice on matters involving the terrain and military operations.

Water Resources

Another major TAC mission involves supporting the DOD Military Hydrology Program. Analysts are developing a worldwide Water Resources Data Base to help commanders locate water for their men and equipment. This automated information system will identify and describe water facilities, surface water features and groundwater resources.

Analysts have prepared a series of topical map overlays which depict such features. The planned data base will supplement these maps, providing detailed evaluative information on specific water sources.

In 1984, TAC surveyed potential data base users to determine the type of information and access needed. Analysts worked with scientists from the U.S. Geological Survey's Water Resources Division to analyze the requirements identified and recommend an appropriate structure for the data base.

Analysts assembling the data base will get much of their information from TAC's extensive collection of books, maps and other materials dealing with water resources. An interactive computer program makes it easy to access, catalog and retrieve these references.

TAC also manages a Water Detection Response Team which will help Army units find water in the field. Formed by the Corps of Engineers, this team of experts will identify and evaluate water sources in support of joint service operations. Scientists from Corps activities, such as ETL and the Waterways Experiment Station, and other government agencies will be available "on call" to handle requests from the field.

Contact: Terrain Analysis Center

US Army Corps
of Engineers